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A report on the fisheries resources of the lower Nelson River and the impacts of hydroelectric development, 1987 data

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Manitoba
Natural Resources
Fisheries

EXECUTIVE SUMMARY

Provincial Fisheries Branch activities in the lower Nelson River watershed continued in the 1987-88 fiscal year. The emphasis of 1987-88 field activities was placed on assessing the degree of impact of ongoing hydroelectric development on the fisheries resources of the area. Of secondary importance was the assessment of techniques which could enhance the fisheries resource or identify areas for enhancement. Thus studies in 1987-88 followed a trend which has evolved since 1985 to move from identification of current impacts to identification of potential impacts and associated mitigative activities to identification of possible enhancement activities.

In an attempt to assess the response of brook trout to the impoundment of portions of the Nelson River twenty brook trout were transfered into the Long Spruce Reservoir-Kettle River system in the fall of 1987. Over the course of the winter 50% of the trout moved out of the system while 50% remained in the Long Spruce Reservoir. No trout selected the Kettle River to overwinter in, however, this may have been due to the confusing effects of being removed from their spawning stream while they were in spawning condition and placed in a strange system. Perhaps spring trout transfers would have a larger proportion of trout which remain in the system.

For the 50% that remained in the system, flooded creek mouths was the preferred habitat. The conclusion drawn from this was that flooded creek mouths seem to be the preferred overwintering habitat in a river-reservoir system. The corollary of this is that a forebay

clearing policy which leaves standing timber will provide cover and more diverse habitat for brook trout and brook trout prey items.

As in previous studies (Swanson 1986; Swanson and Kansas 1987) strontium data indicated low levels of anadromy in the area. Limestone Forebay tributaries (Wilson and Sky Pilot Creek) had a combined level of anadromy of 2.5% (3 of 121 trout sampled) while 1.5% of Limestone River trout were considered anadromous (3 of 174 trout sampled). These low levels are however believed to be misrepresentative of the levels that would be observed in a less exploited/disturbed population. In fact, if proximity to Hudson Bay is proportional to the level of anadromy, Limestone River trout may have exhibited a level of anadromy of 24% at a level of exploitation similar to that which currently exists on Weir River stocks.

Movements of brook trout into and out of three small tributaries were studied. It was noted that all three streams served as nursery habitat with few large adult trout actually entering the streams. Spawning was discovered in two of these streams (CN and Moondance Creeks) and was very closely related to the presence of groundwater. Likewise the distribution of young-of-the-year brook trout was highly contagious with high densities of these trout in groundwater areas. areas. The third creek sampled was a north shore Conawapa Forebay tributary (unnamed but referred to as"Beaver Creek"). No evidence supporting brook trout spawning was discovered in Beaver Creek and young-of-the-year trout were observed immigrating into Beaver Creek in the spring. It is believed that Beaver Creek and other north shore tributaries in the Conawapa Forebay serve as refuge for immature brook from a turbid environment and a rapidly varying flow regime in the Nelson River proper. While the presence of spawning in Conawapa Forebay north shore tributaries is possible the significance of any spawning activity in these streams is not believed to be high relative to that in larger known trout spawning streams. These studies confirmed previous hypotheses regarding the need for fish passage requirements for small trout at Conawapa Access Road stream crossings and the significance of groundwater in the life history of Nelson River brook trout. They also provided evidence which supports concerns regarding borrow pit development and its potential impact on groundwater.

An attempt to locate groundwater upwellings was partially successful. The Federal Department of Fisheries and Oceans' Forward Looking Infra Red (FLIR) device was used on loan and operated by E.M.S.I., Ltd. to locate coldwater upwellings in lower Nelson River tributaries. Problems were encountered primarily with the navigational system used. Moreover a small leak in a vacuum chamber of the FLIR reduced the sensitivity of the system. The data which was generated was of limited use for identifying specific groundwater upwellings but was useful in identifying larger reaches of the streams surveyed where groundwater upwellings were abundant. When this data was compared to Manitoba Hydro potential borrow sites and existing borrow sites a correlation was noted between granular borrow sites (unconfined groundwater aquifers) and groundwater upwellings in streams. Several recommendations are included in this report to mitigate the impacts of aggegate borrow operations.

Netting in the Nelson River proper was attempted however damage to the outboard motor as a consequence of the drought flow regime abbreviated the sampling program. The data that was generated indicated that sturgeon were present in Angling Lake and that Angling Lake and Nelson River lake sturgeon grow similarly and are therefore hypothesized to be of the same stock. Radio telemetry data supported this with two missing radio tags located in Angling Lake in the winter of 1987-88. Two other areas were identified as important for lake sturgeon these being Jackfish Island, used for overwintering, and the Nelson River estuary, used for summer habitat and overwintering. Information which does not currently exist is the location of lake sturgeon spawning and the contribution of Angling Lake to the Nelson River lake sturgeon stock.

Other fisheries resources of Angling Lake appear to be legally harvested at a rate suitable to maintain a high quality walleye and northern pike sport fishery there. No conflict between current sport fishery harvest levels and domestic fishery use is apparent however increased access would increase the level of effort for both types of fishing. For these reasons it was recommended that Angling Lake access not be enhanced via winter or all weather roads. Furthermore regular enforcement patrols are required both to monitor the level of utilization and to reduce the level of illegal netting which has been observed in Angling Lake the last two years.

Finally, 1987-88 was the first year of the long term brook trout monitoring program. As such the program monitored brook trout drift, juvenile trout habitat utilization, movements of Floy tagged brook trout and relative abundance of spawning brook trout (year to year trends rather than stream to stream). Moreover, the program includes Limestone Forebay tributaries as well as tributaries which won't be impounded (i.e. control streams). The use of control streams is intended to help factor out year to year variation due to environmental circumstances other than the hydroelectric impacts.

ACKNOWLEDGEMENTS

This study would not have been possible without the funding and support provided by Manitoba Hydro. Manitoba Hydro provided accommodation and storage facilities for Fisheries Branch field staff at the Limestone construction camp. The assistance of Messrs. D. Windsor, P. Porter and W. McCaskie with respect to this are particularly appreciated. The authors also wish to express their gratitude to D. Cook and G. McVittie (Fisheries Branch Northeast Region), J. Beyette (Fisheries Branch Southeastern Region), I. Hagenson and R. Janusz (Fisheries Branch Enhancement Section) for the timely availability of gear required for a project of this magnitude. Thanks are also due to P. Roberts (N.R.O. Sundance) and C. McNairnay (N.R.O. Gillam) for their assistance with radio telemetry flights and Mr. D. Snuggs (Energy and Mines Branch) for his assistance and analysis of brook trout fin ray strontium content. The FLIR device was loaned to the Department of Natural Resources by the Federal Department of Fisheries and Oceans, Freshwater Institute, Winnipeg and the authors appreciate the assistance of Mr. G. Yaremchuk in this regard.

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IMPOUNDMENT/BROOK TROUT ANADROMY

INTRODUCTION

Fundamental to predicting the impacts of hydro-electric development on brook trout (Salvelinus fontinalis) in the lower Nelson River is an understanding of the role that "anadromy" plays in brook trout life history. A number of studies have addressed this issue in the past. Historically Nelson River brook trout were considered "anadromous"; the implications being that a vast majority of these trout migrated from feeding areas in Hudson Bay to spawning tributaries of the Nelson River annually. Studies in the late 1970's used strontium levels as an indication of anadromy (Gaboury 1980). The theory was that strontium uptake in bony tissues is greater in salt water than in freshwater (Ophel and Judd 1968). More recently (mid to late 1980's) radio telemetry has been used to supplement strontium data in assessing anadromy and brook trout movements in the unimpounded Nelson River (Swanson 1986; Swanson and Kansas 1987). Both types of analysis have determined that a relatively small portion (in numbers) of Limestone River brook trout are likely to be adversely impacted by the loss of movements to Hudson Bay past the proposed Conawapa Generating Station site. It is more likely that habitat changes in the Nelson River from a shallow fast flowing river to a deeper, slower moving reservoir will be a greater negative impact on brook trout (Swanson 1986; Swanson and Kansas 1987).

Since none of the previous studies assessed the contribution of habitat change versus that of migration barrier, studies were undertaken in the fall/winter of 1987/88 to determine the effects of impoundment on brook trout. Assessment of brook trout fin ray strontium levels were also done as a matter of course in all other studies undertaken in 1987/88 and data are presented here.

METHODS

Radio Telemetry

A total of twenty brook trout were captured in the Limestone River (n=9) and Weir River (n=11) and transferred to the Long Spruce Reservoir-Kettle River system in the fall of 1987. Trout were captured by angling and transferred in 17 gallon tubs without anaesthetic by helicopter. Transfer densities were approximately one trout per 27 litres and flights were a maximum of twenty minutes in duration. Trout were held in a 1.2 x 1.2 x 2.4 m pen at the mouth of the Kettle River to acclimate for 2-7 days.

Brook trout were tagged with 15g, externally mounted, 200 day life radio tags. Tagging procedures were as previously described (Swanson 1986) and brook trout were transported to release sites by helicopter from the holding pen. Radio tagging information is presented in Table 1 and release locations are indicated in Figure 1.

Radio tagged brook trout were located approximately bi-weekly using a one-quarter wavelength directional loop antennae mounted on a Bell 206 Jet Ranger helicopter (Custom Helicopters Ltd., Gillam, Manitoba) as per previous studies (Swanson 1986; Swanson and Kansas 1987). Those transmitters which were not located outside of the reservoir for the duration of the study, or were not located in the reservoir after January 7, 1988 were classified into an "Unknown" category. Other radio transmitters were categorized into "In" and "Out" of the reservoir groups.

Table 1. Radio tagging information for brook trout transferred into Long Spruce Reservoir in 1987.

Origin	Release Date	Release Site	FL (mm)	Weight (g)	Age (years)	Sex	Tag Frequency	Comments
Limestone R.	13-Aug-87	mouth of the Kettle R.	520	1400	5	m	49.328	skinny
Limestone R.	13-Aug-87	mouth of the Kettle R.	468	1900	4	m	49.550	pre-maxilla stripped
Limestone R.	13-Aug-87	mouth of the Kettle R.	483	1400	4	f	49.592	good condition
Weir R.	07-Sep-87	reservoir	568	2550	6	m	49.280	good condition
Weir R.	07-Sep-87	spawning pool	510	1750	4	f	49.420	good condition
Weir R.	07-Sep-87	spawning pool	462	1150	4	f	49.378	good condition
Weir R.	07-Sep-87	reservoir	432	900	3	f	49.568	good condition
Weir R.	07-Sep-87	spawning pool	487	1450	5	m	49.350	good condition
Weir R.	27-Sep-87	mouth of the Kettle R.	535	1650	5	f	49.250	good condition
Limestone R.	27-Sep-87	mouth of the Kettle R.	490	1350	4	m	49.310	good condition
Weir R.	27-Sep-87	mouth of the Kettle R.	475	1100	5	m	49.200	good condition
Limestone R.	27-Sep-87	mouth of the Kettle R.	552	1950	7	m	49.158	good condition
Weir R.	27-Sep-87	reservoir	502	1400	5	m	49.489	good condition
Limestone R.	27-Sep-87	reservoir	486	1200	5	m	49.078	good condition
Limestone R.	27-Sep-87	reservoir	429	900	4	m	49.099	good condition
Weir R.	27-Sep-87	reservoir	449	950	3	m	49.178	good condition
Weir R.	27-Sep-87	spawning pool	547	1550	5	f	49.138	good condition
Limestone R.	27-Sep-87	spawning pool	500	1450	4	m	49.117	recapture 1001439
Weir R.	27-Sep-87	spawning pool	481	1100	4	f	49.038	good condition
Limestone R.	27-Sep-87	spawning pool	349	450	3	m	49.058	left eye bulged out

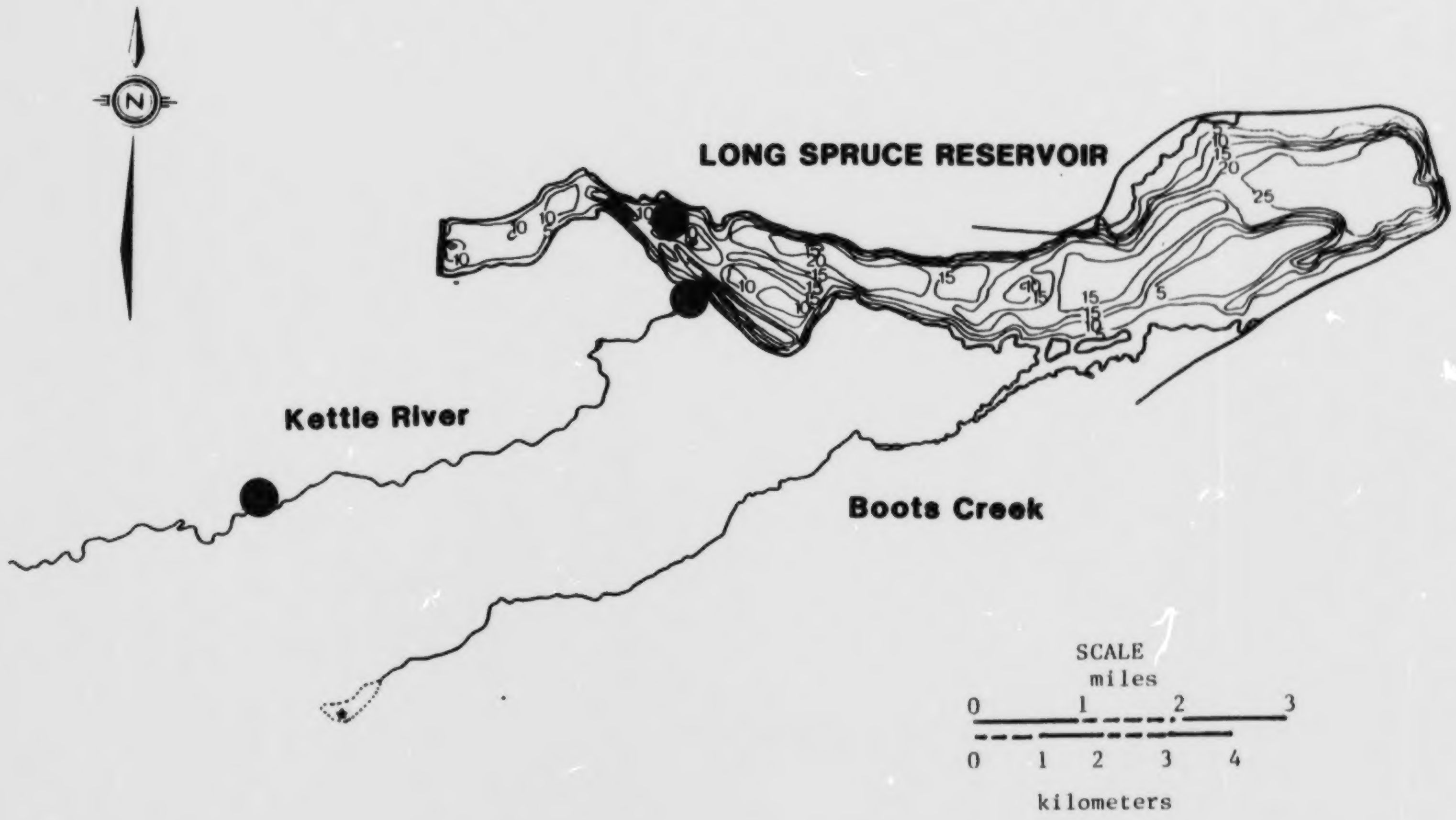

LONG SPRUCE RESERVOIR
Kettle River
Boots Creek
N
10
15
20
25
5
SCALE
miles
0
1
2
3
0
1
2
3
4
kilometers

Figure 1: Brook trout transfer locations into the Kettle River-Long Spruce Reservoir system in 1987. Contours in meters.

Strontium

Brook trout sampled in 1987 had one pelvic fin removed for strontium analyses. Sample preparation was as per Swanson (1986) and Swanson and Kansas (1987) using perchloric acid to digest fin ray organic tissue. Nitric acid (0.1%) and calcium carbonate were then added in a 9:1 ratio. Solution strontium levels were determined using atomic absorption with a Varian AA975 spectrophotometer and later corrected for the amount of fin ray used for each sample. All samples were analyzed by D. Snuggs of the Manitoba Department of Energy and Mines.

RESULTS

Radio Telemetry

Of the twenty brook trout transferred, radio tagged and released into the Long Spruce Reservoir-Kettle River system, four were classified as "Unknown" because they are not consistently located (frequencies 49.328, 49.158, 49.178 and 49.038 Mhz). Additionally, tag frequency 49.592 Mhz was deleted from further consideration after it was returned to the Gillam Natural Resources office; reportedly found on the north shore of Stephens Lake. Tag locations for each of the seven "Out" and eight "In" brook trout and for two of the "Unknown" brook trout are presented in Figures 2-18. Locations for transmitters 49.178 and 49.158 Mhz are not presented as these tags were not located after their release on September 27, 1988.

Some evidence was gathered to indicate that trout from the Limestone River and trout released into the spawning pool in the Kettle River remained in the Long Spruce Reservoir-Kettle River system longer than did other brook trout (Table 2). Of the Limestone River trout 50% were still in the system on January 7, 1988 compared to 36.4% of the Weir River trout. Furthermore 57.1% of all the trout (Limestone and Weir Rivers combined) released upstream into the Kettle River spawning pool were still in the system as of January 3 whereas only 33.3% of the trout released at the other two sites remained in the system.

While data indicates that more males than females remained in the system (46.2% versus 33.3%) and that greater numbers of young trout ($\leq$4+ years) remained than older trout ($\geq$5+ years), (50.0% versus 33.3%)

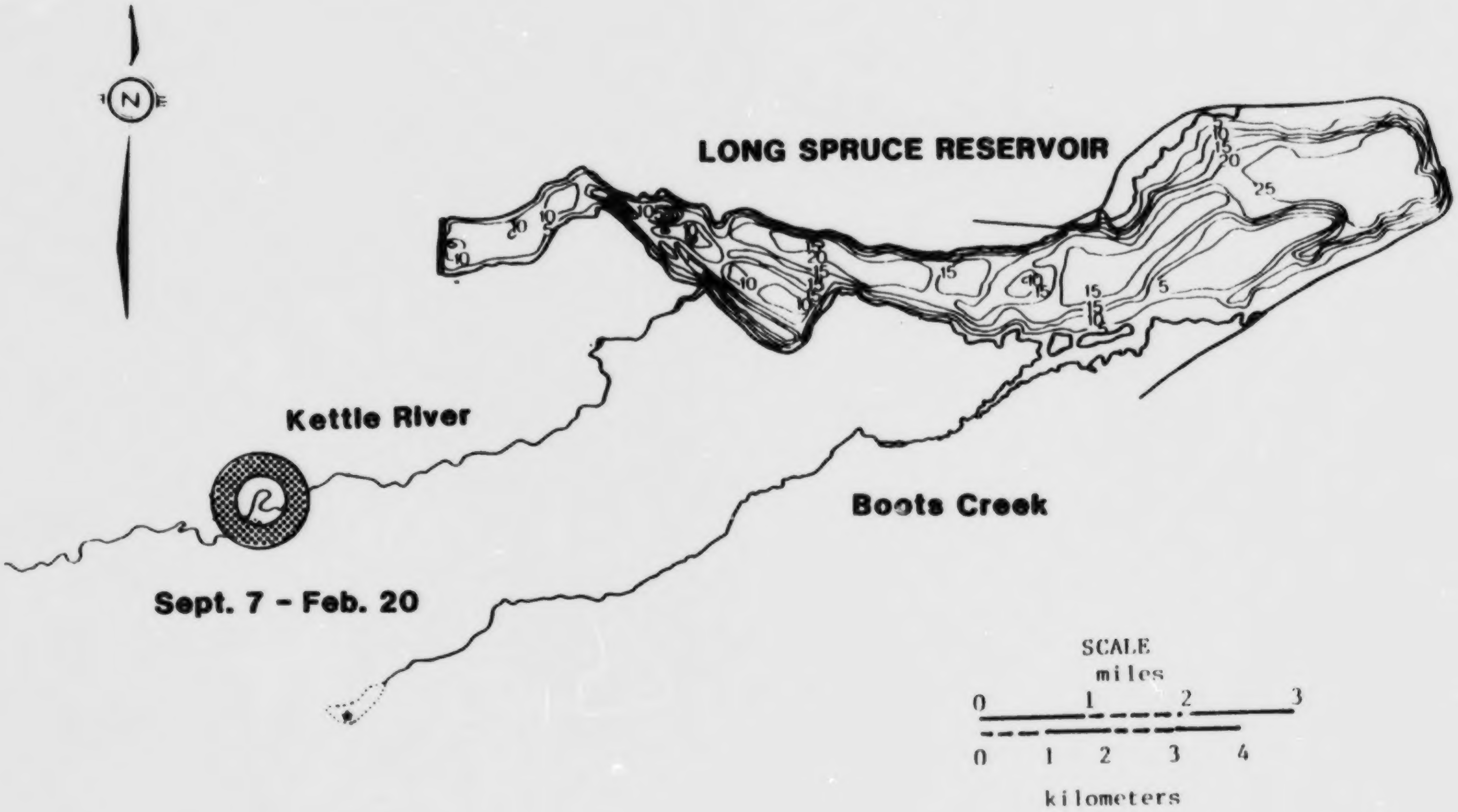

N
LONG SPRUCE RESERVOIR
Kettle River
Boots Creek
Sept. 7 - Feb. 20
SCALE
miles
0 1 2 3
0 1 2 3 4
kilometers

Figure 2: Locations of radio tagged trout 49.378 Mhz in 1987-88.

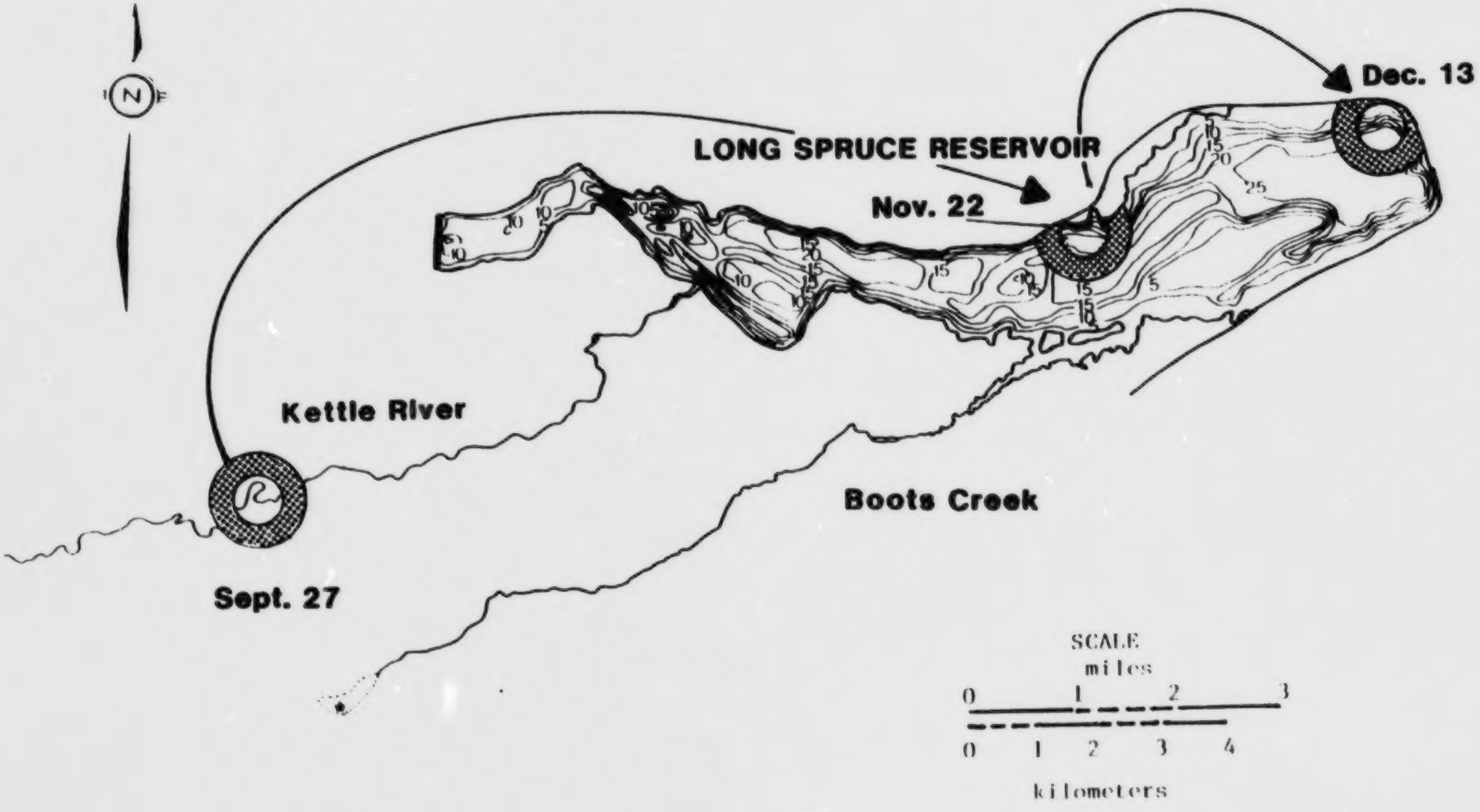

N
Dec. 13
LONG SPRUCE RESERVOIR
Nov. 22
Kettle River
Boots Creek
Sept. 27
SCALE
miles
0 1 2 3
0 1 2 3 4
kilometers

Figure 3: Locations of radio tagged trout 49.038 Mhz in 1987-88.

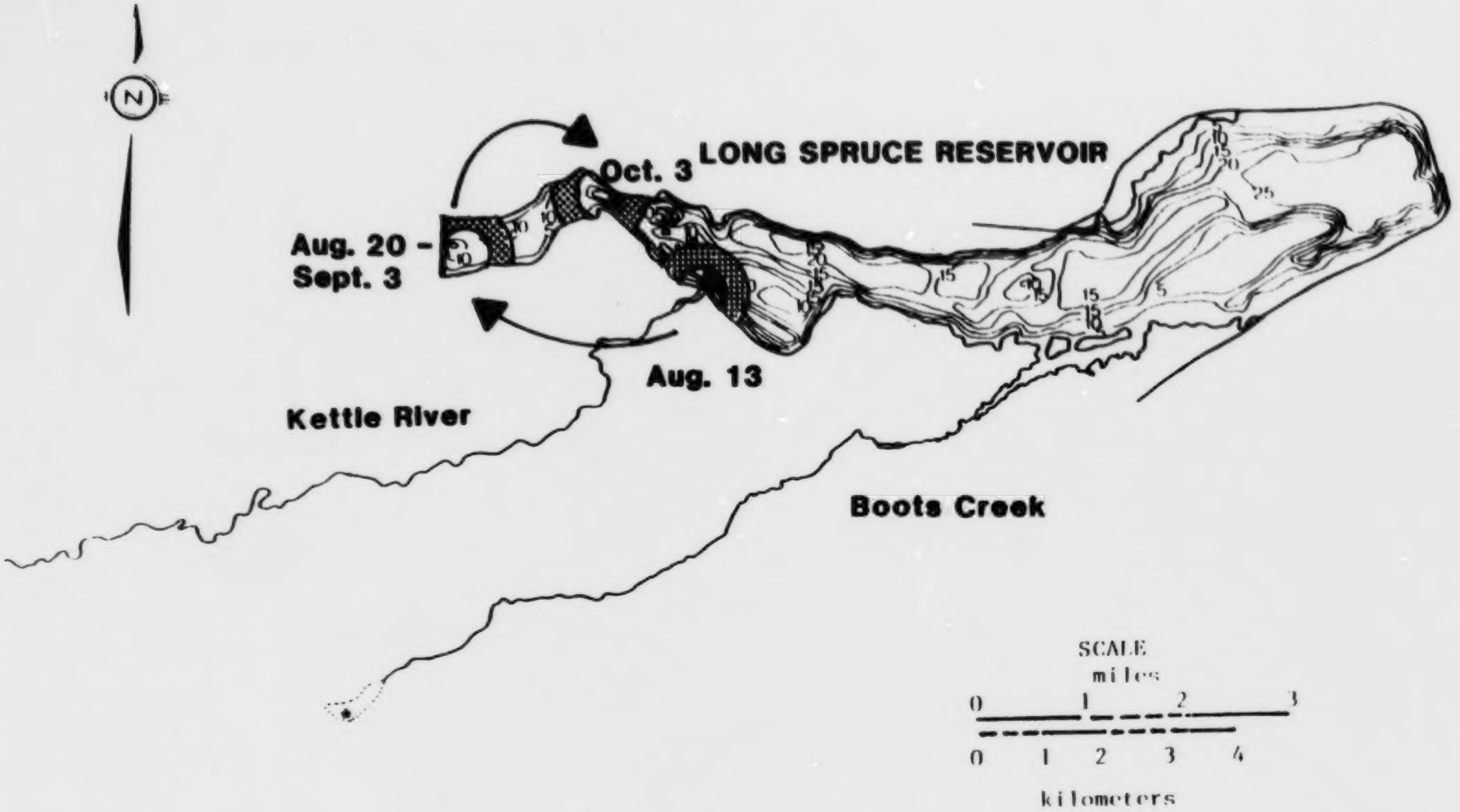

N
LONG SPRUCE RESERVOIR
Oct. 3
Aug. 20 -
Sept. 3
Aug. 13
Kettle River
Boots Creek
SCALE
miles
0
1
2
3
0
1
2
3
4
kilometers

Figure 4: Locations of radio tagged trout 49.328 Mhz in 1987-88.

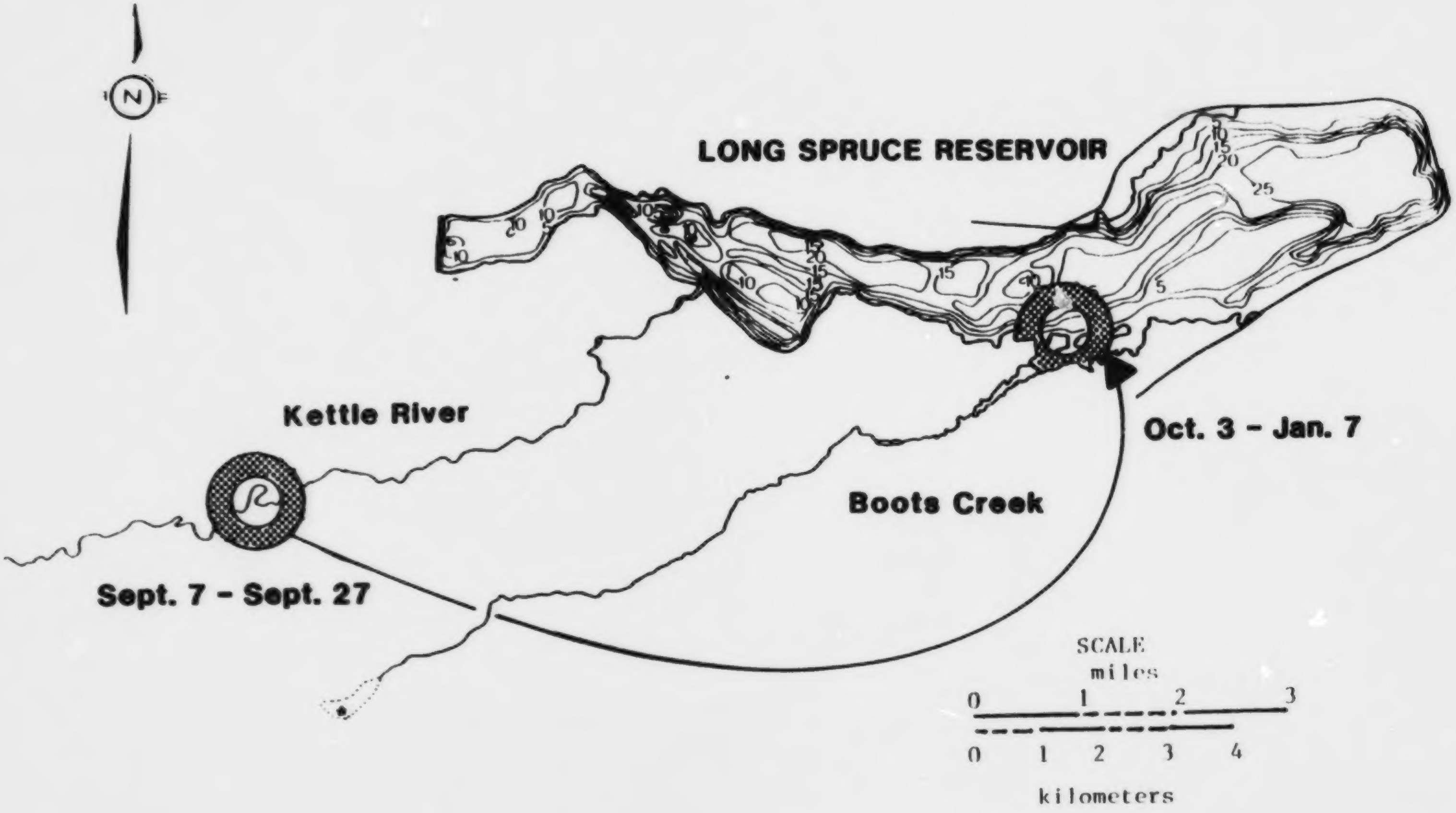

N
LONG SPRUCE RESERVOIR
Kettle River
Boots Creek
Oct. 3 - Jan. 7
Sept. 7 - Sept. 27
SCALE
miles
0
1
2
3
0
1
2
3
4
kilometers

Figure 5: Locations of radio tagged trout 49.350 Mhz in 1987-88.

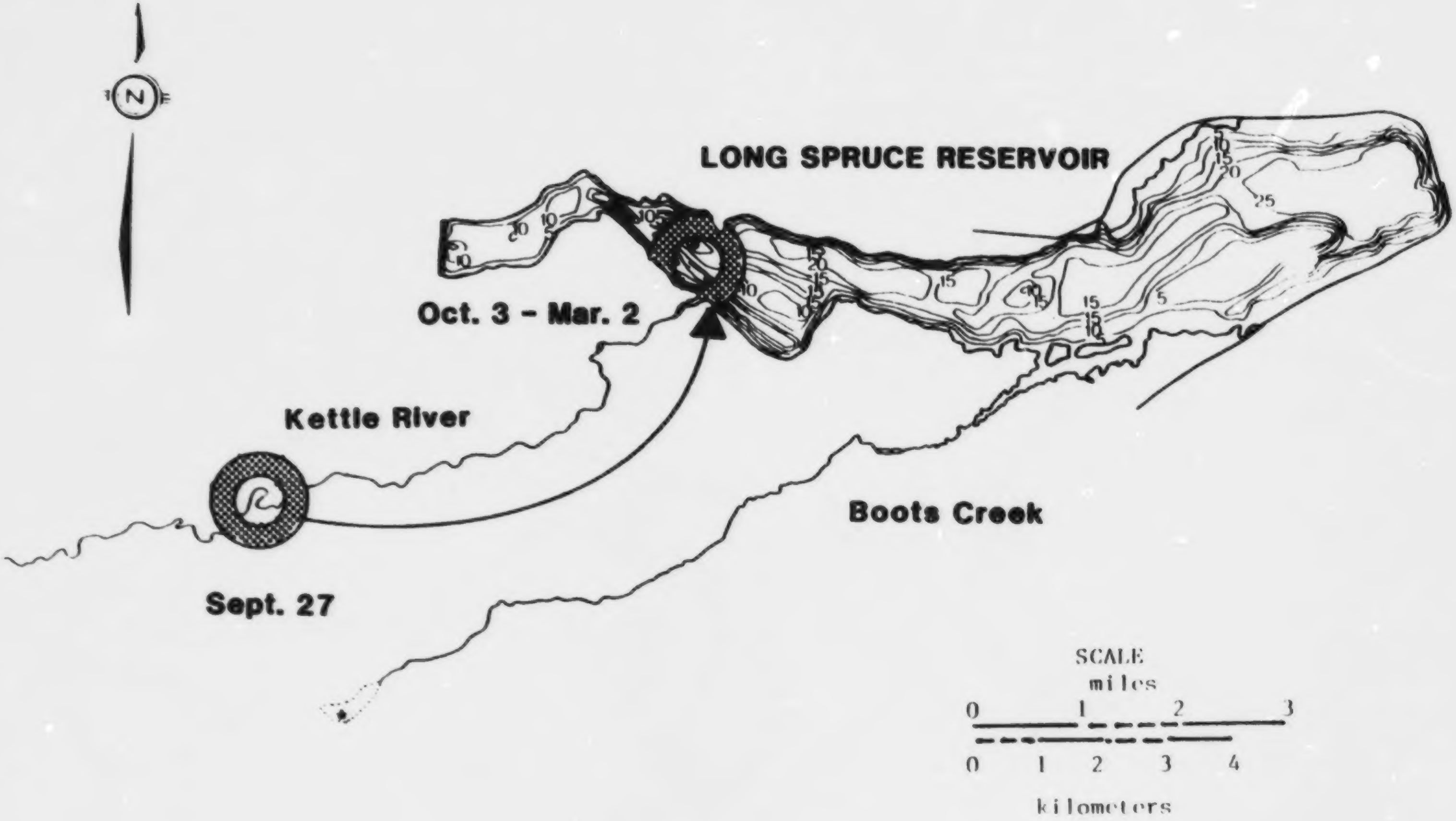

N
LONG SPRUCE RESERVOIR
Oct. 3 - Mar. 2
Kettle River
Sept. 27
Boots Creek
SCALE
miles
0
1
2
3
0
1
2
3
4
kilometers

Figure 6: Locations of radio tagged trout 49.138 Mhz in 1987-88.

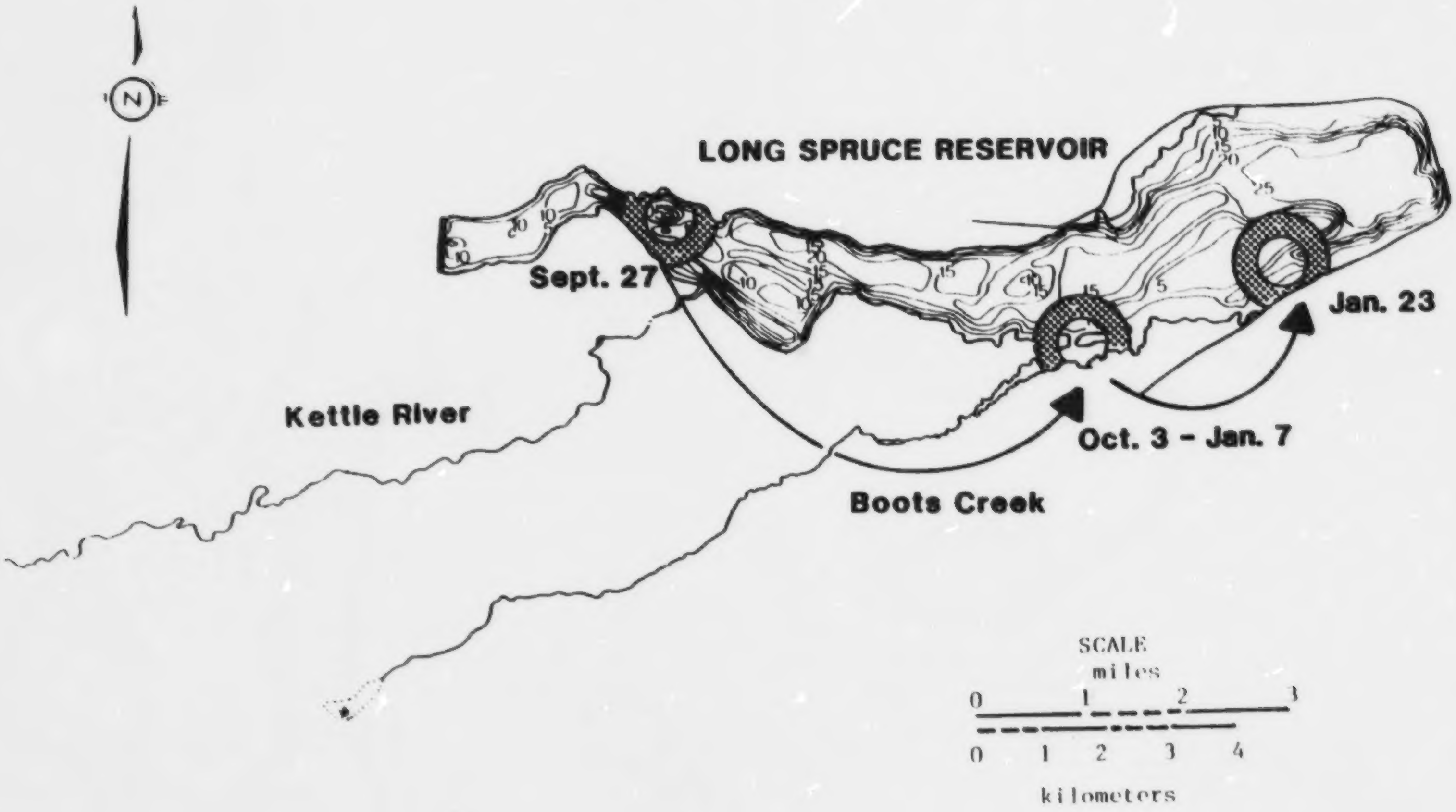

N
LONG SPRUCE RESERVOIR
Sept. 27
Jan. 23
Oct. 3 - Jan. 7
Kettle River
Boots Creek
SCALE
miles
0
1
2
3
0
1
2
3
4
kilometers

Figure 7: Locations of radio tagged trout 49.099 Mhz in 1987-88.

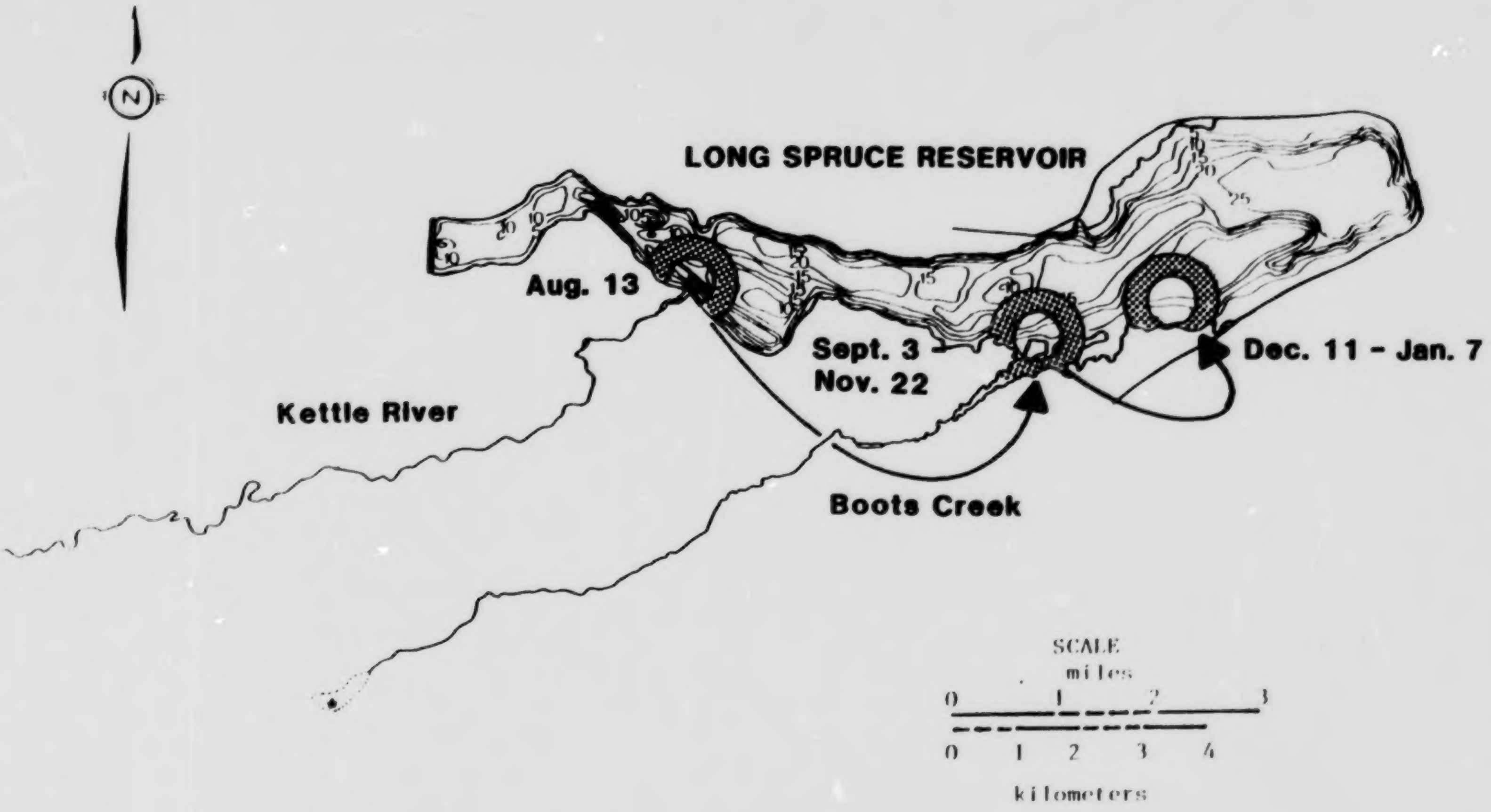

LONG SPRUCE RESERVOIR
N
Aug. 13
Sept. 3 -
Nov. 22
Dec. 11 - Jan. 7
Kettle River
Boots Creek
SCALE
miles
0
1
2
3
0
1
2
3
4
kilometers

Figure 8: Locations of radio tagged trout 49.550 Mhz in 1987-88.

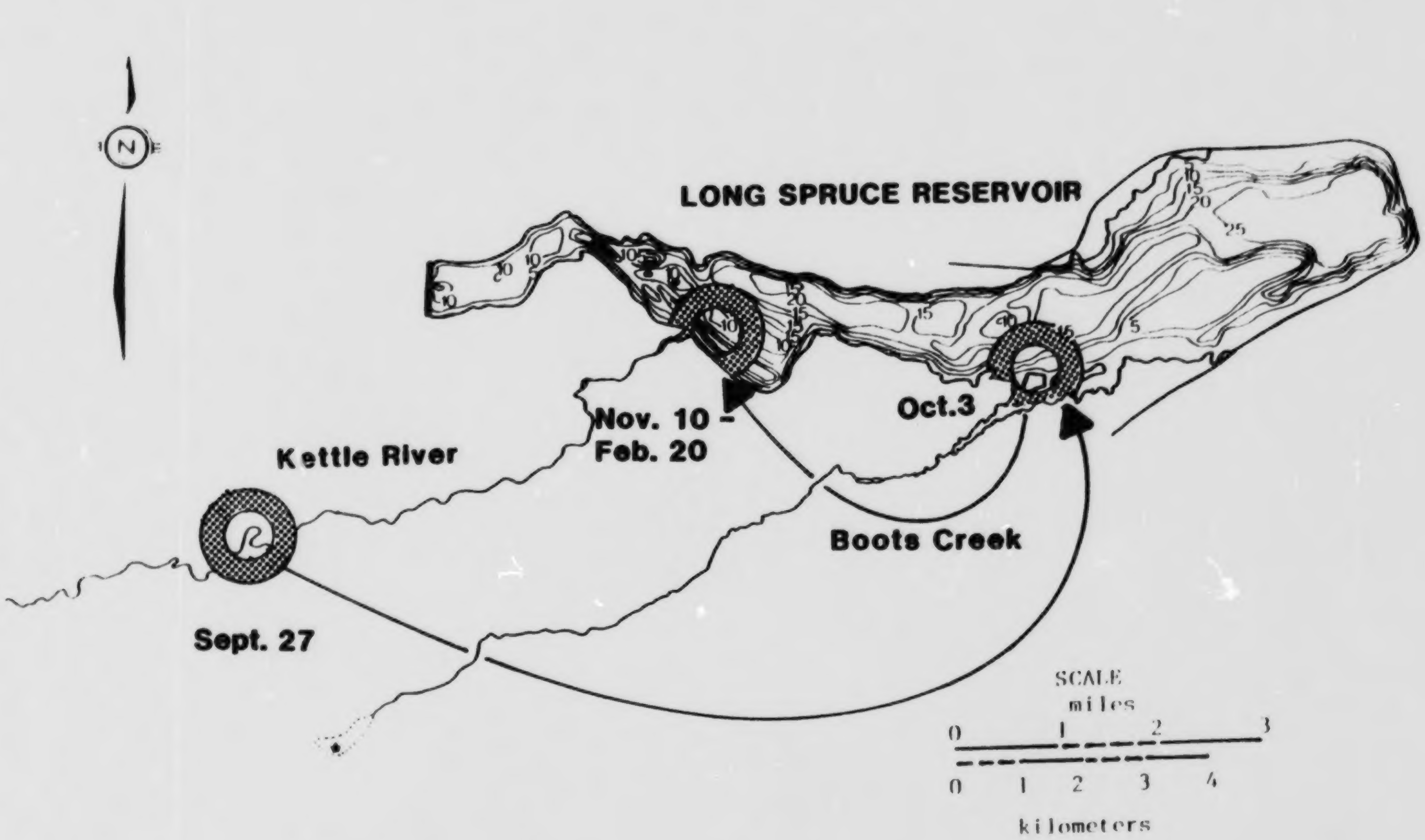

LONG SPRUCE RESERVOIR
N
Kettle River
Boots Creek
Sept. 27
Nov. 10 -
Feb. 20
Oct.3
SCALE
miles
0 1 2 3
0 1 2 3 4
kilometers
10
15
20
25
5
30

Figure 9: Locations of radio tagged trout 49.058 Mhz in 1987-88.

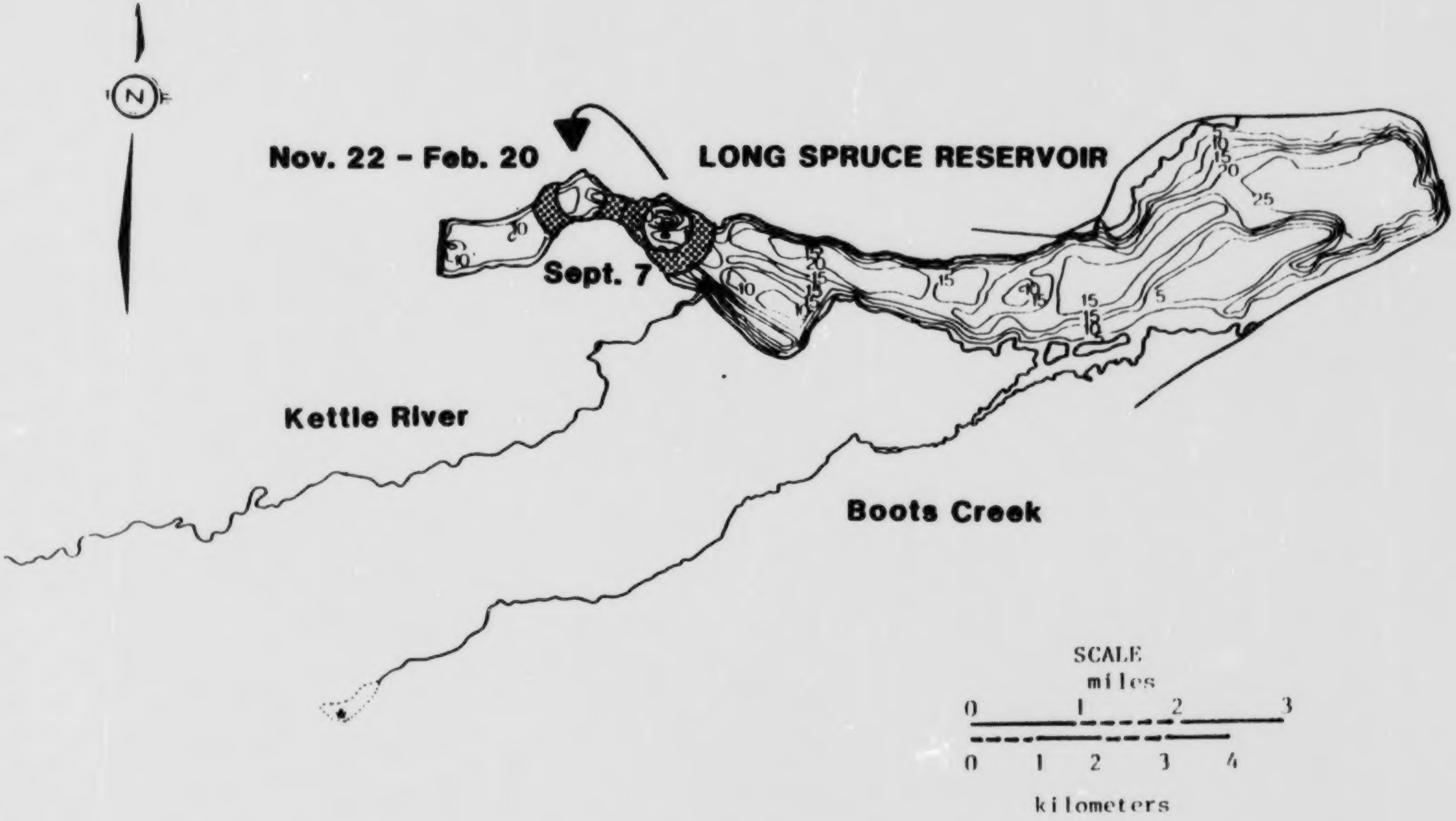

N
Nov. 22 - Feb. 20
LONG SPRUCE RESERVOIR
Sept. 7
Kettle River
Boots Creek
SCALE
miles
0
1
2
3
0
1
2
3
4
kilometers

Figure 10: Locations of radio tagged trout 49.280 Mhz in 1987-88.

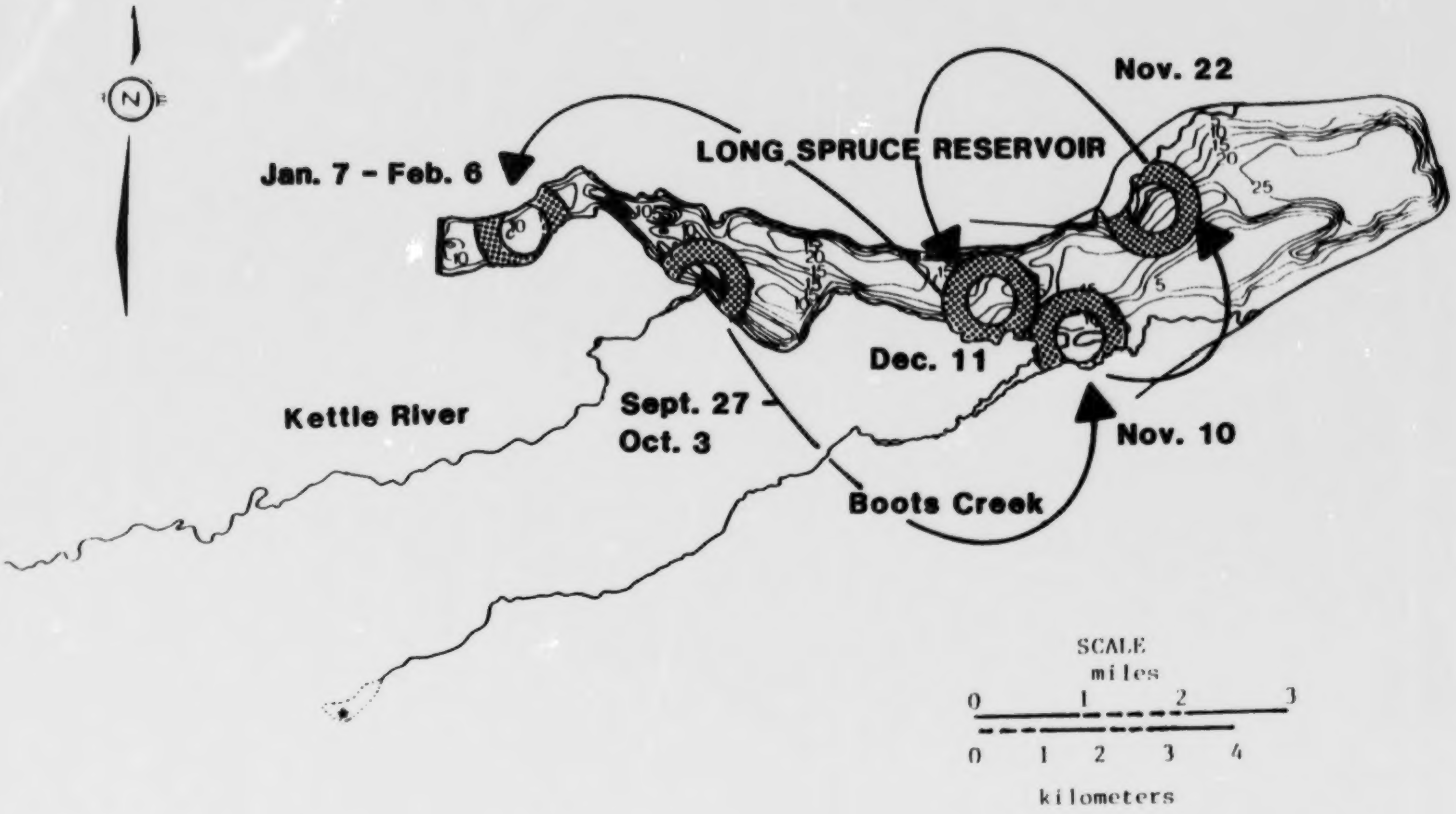

Z
Nov. 22
LONG SPRUCE RESERVOIR
Jan. 7 - Feb. 6
Dec. 11
Kettle River
Sept. 27 - Oct. 3
Nov. 10
Boots Creek
SCALE
miles
0 1 2 3
0 1 2 3 4
kilometers

Figure 11: Locations of radio tagged trout 49.310 Mhz in 1987-88.

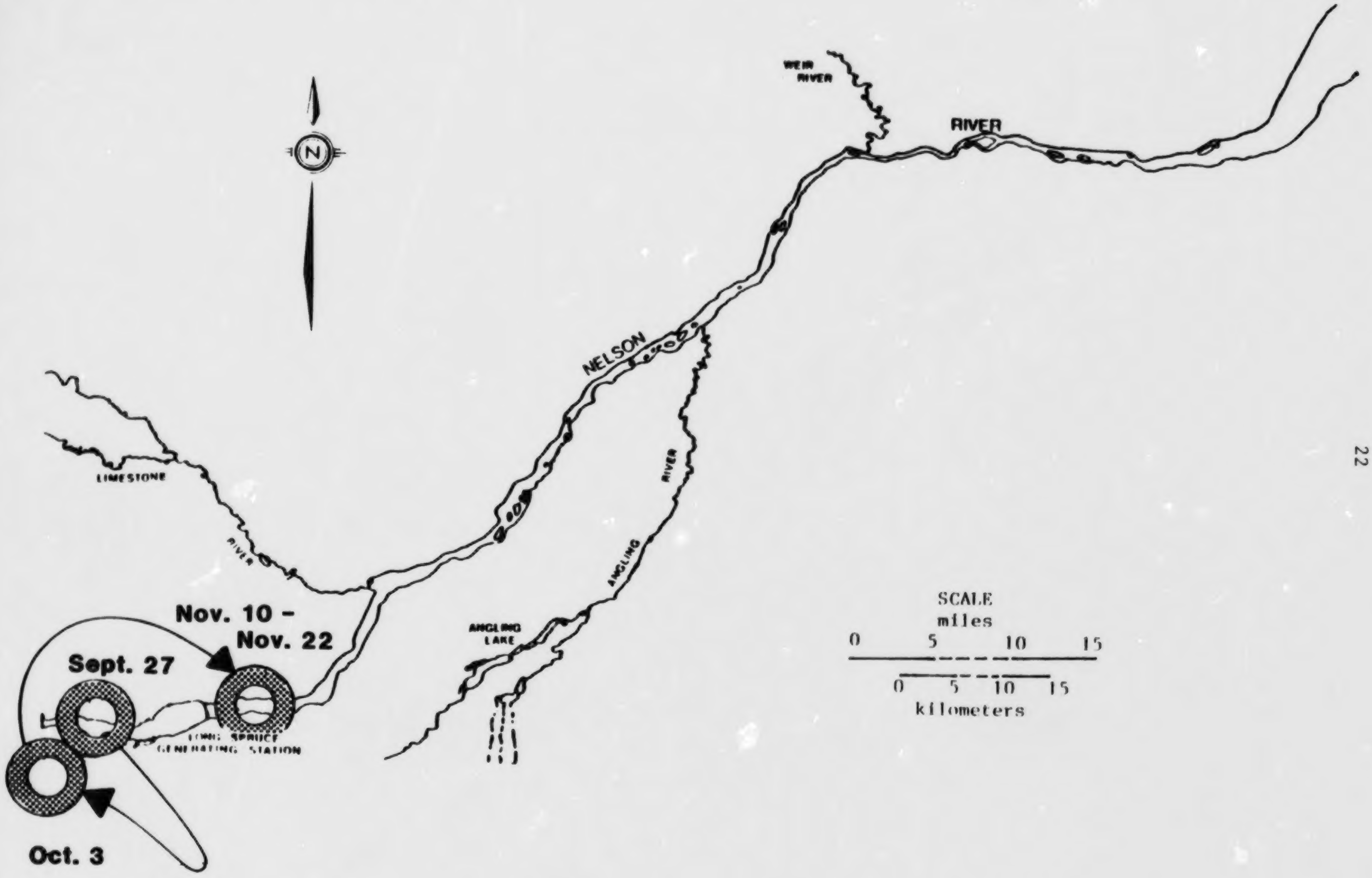

N
WEIR RIVER
RIVER
NELSON
LIMESTONE
RIVER
ANGLING RIVER
ANGLING LAKE
LONG SPRUCE GENERATING STATION
Nov. 10 - Nov. 22
Sept. 27
Oct. 3
SCALE
miles
0
5
10
15
0
5
10
15
kilometers

Figure 12: Locations of radio tagged trout 49.489 Mhz in 1987-88.

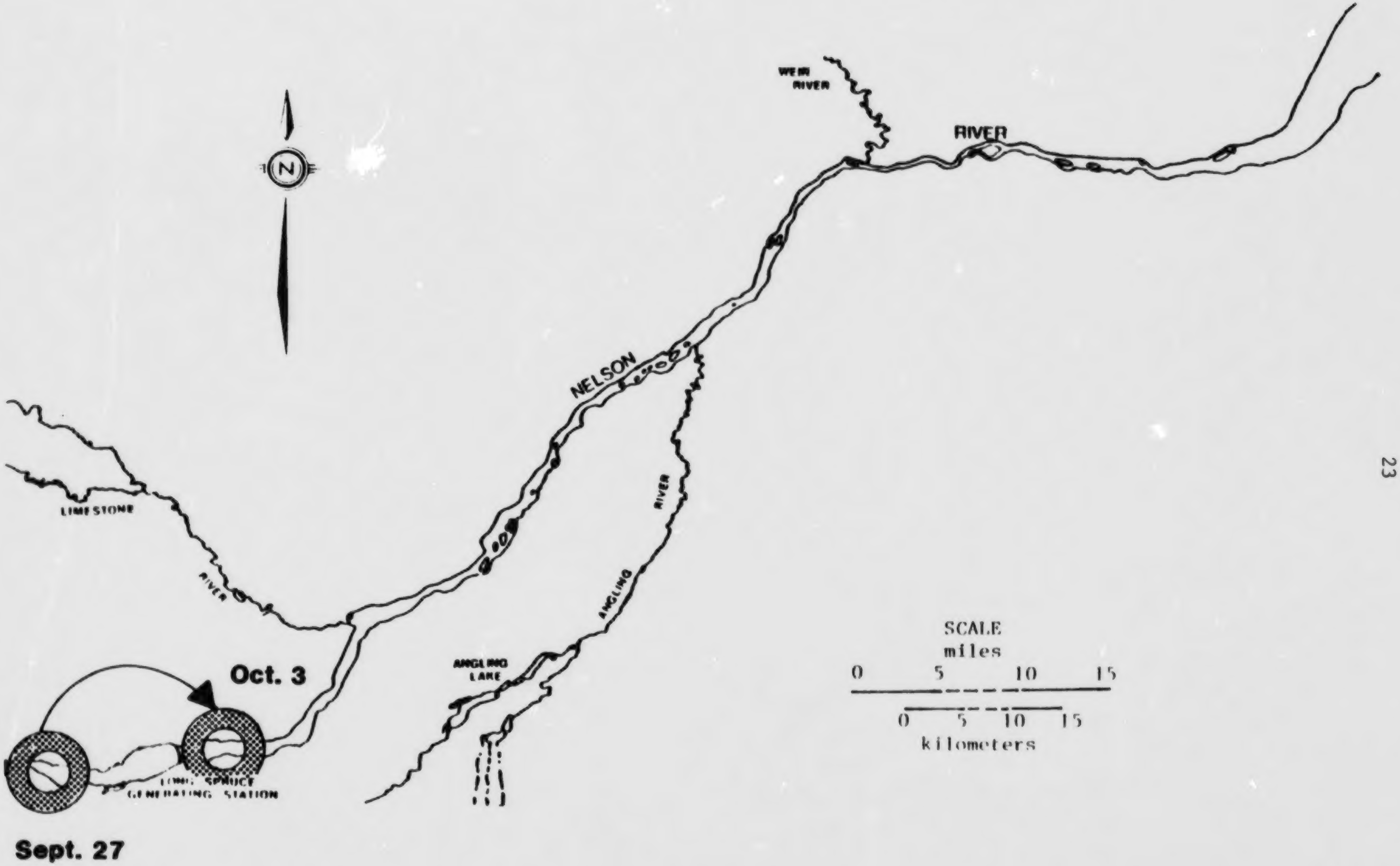

WEIR RIVER
RIVER
NELSON
LIMESTONE
RIVER
ANGLING RIVER
ANGLING LAKE
N
Oct. 3
LONG SPRUCE GENERATING STATION
Sept. 27
SCALE
miles
0 5 10 15
0 5 10 15
kilometers

Figure 13: Locations of radio tagged trout 49.250 Mhz in 1987-88.

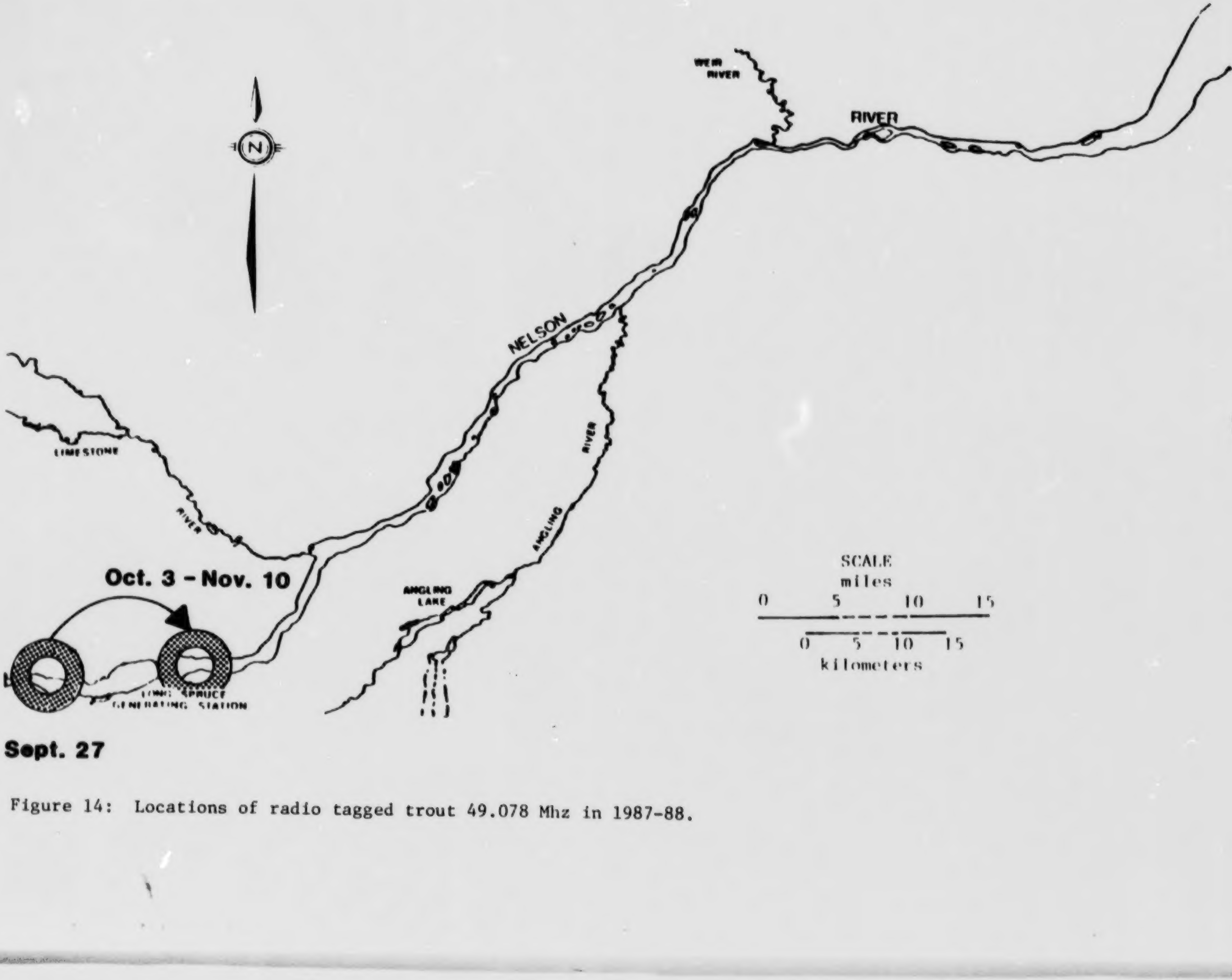

N
WEIR RIVER
RIVER
NELSON
LIMESTONE
RIVER
RIVER
ANGLING
ANGLING LAKE
Oct. 3 - Nov. 10
LONG SPRUCE GENERATING STATION
Sept. 27
SCALE
miles
0
5
10
15
0
5
10
15
kilometers

Figure 14: Locations of radio tagged trout 49.078 Mhz in 1987-88.

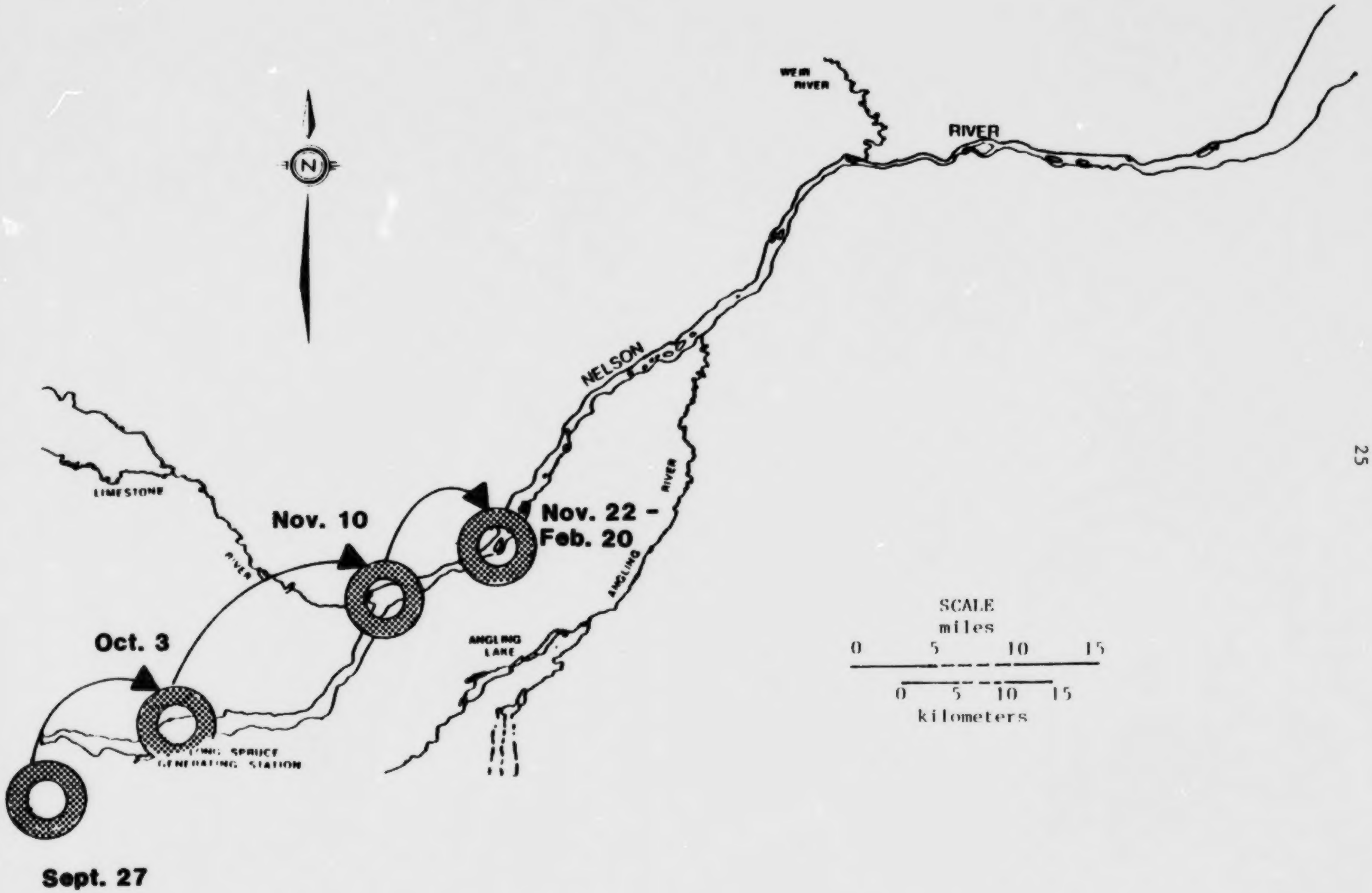

WEIR RIVER
RIVER
NELSON
LIMESTONE
RIVER
Nov. 10
Nov. 22 -
Feb. 20
ANGLING RIVER
ANGLING LAKE
Oct. 3
LONG SPRUCE GENERATING STATION
Sept. 27
N
SCALE
miles
0
5
10
15
0
5
10
15
kilometers

Figure 15: Locations of radio tagged trout 49.117 Mhz in 1987-88.

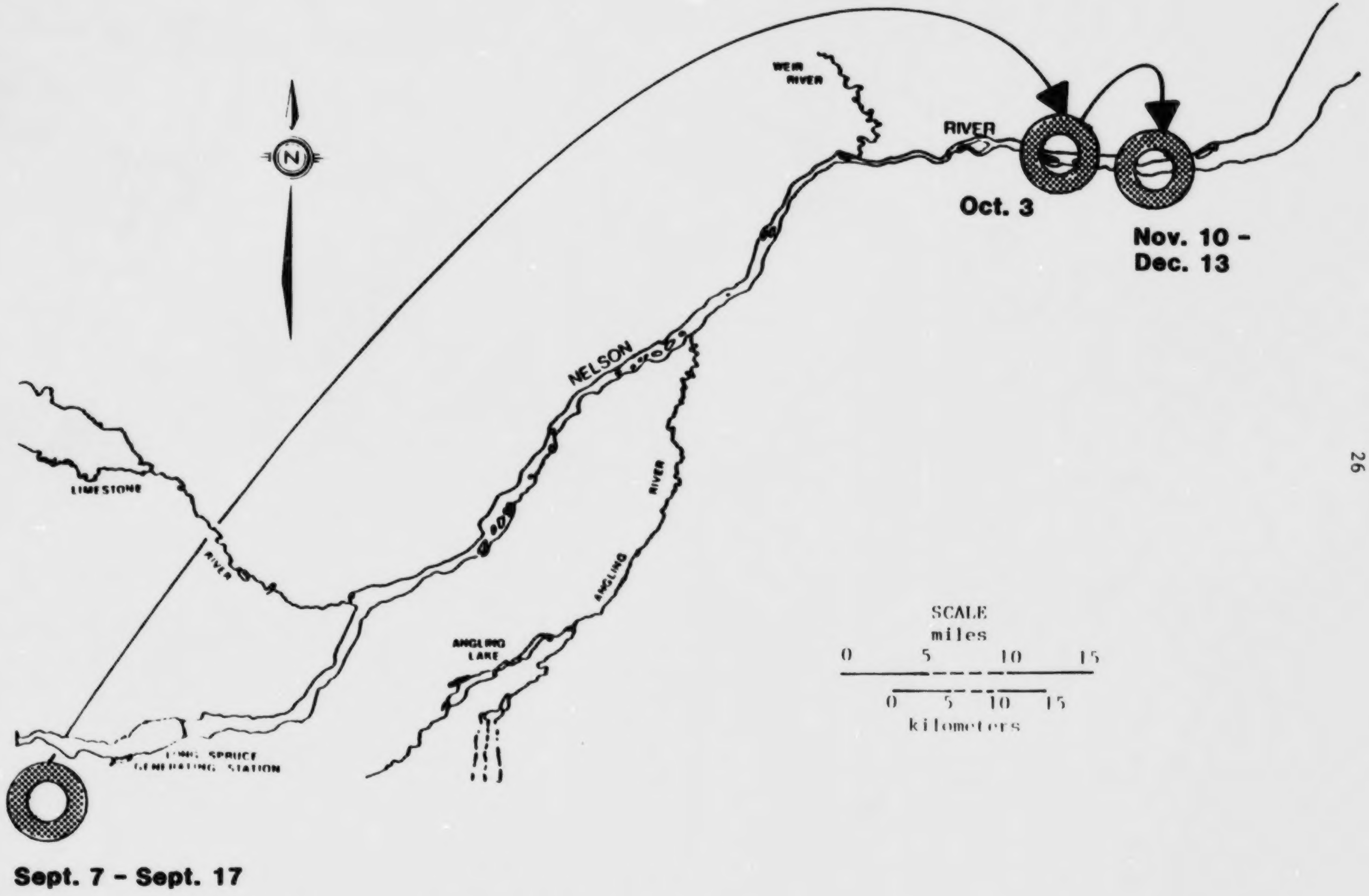

N
WEIR RIVER
RIVER
Oct. 3
Nov. 10 -
Dec. 13
NELSON
LIMESTONE
RIVER
RIVER
ANGLING
ANGLING LAKE
LONG SPRUCE GENERATING STATION
SCALE
miles
0
5
10
15
0
5
10
15
kilometers
Sept. 7 - Sept. 17

Figure 16: Locations of radio tagged trout 49.420 Mhz in 1987-88.

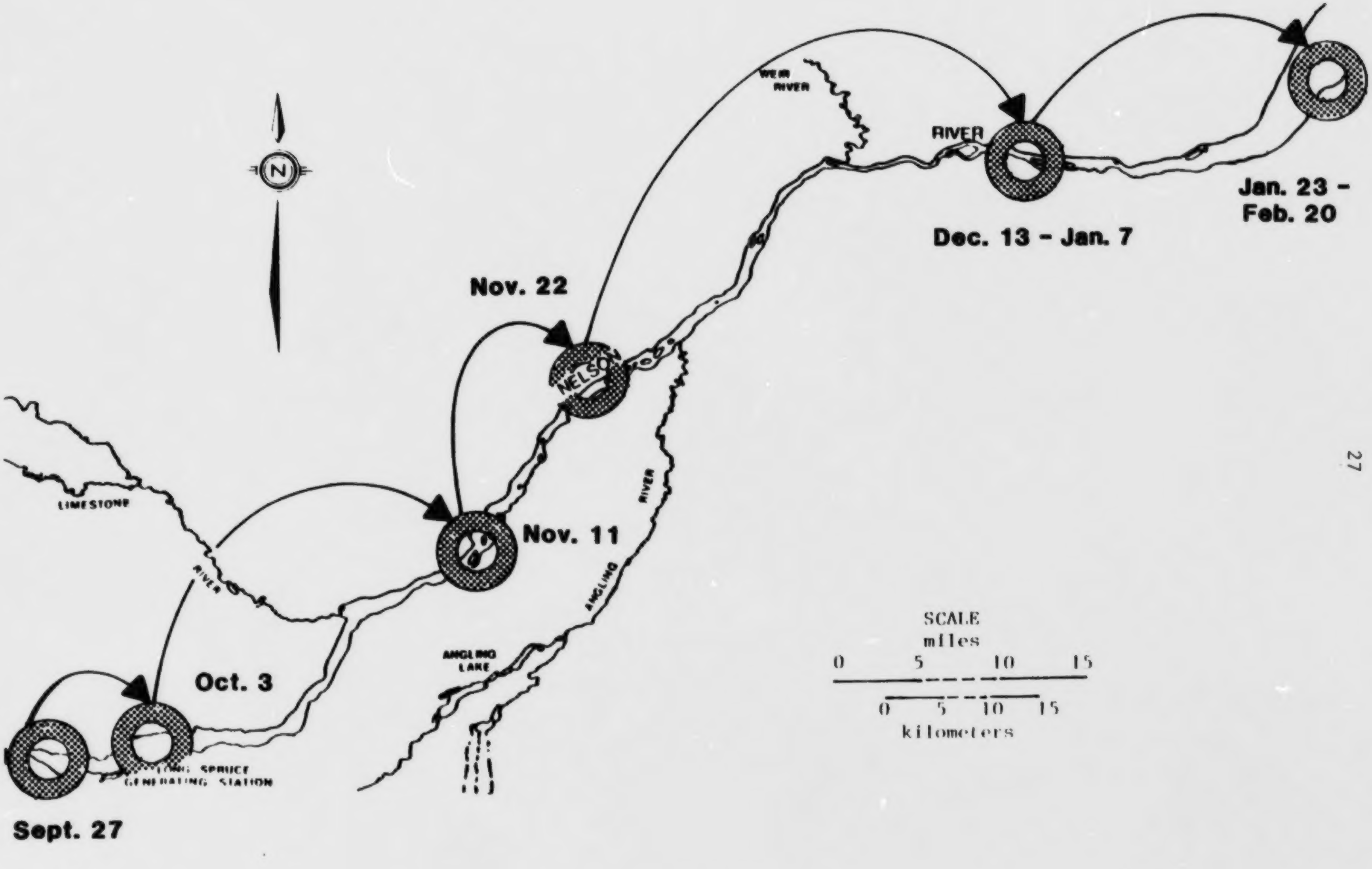

N
WEIR RIVER
RIVER
Jan. 23 -
Feb. 20
Dec. 13 - Jan. 7
Nov. 22
NELSON
LIMESTONE
RIVER
Nov. 11
RIVER
ANGLING
ANGLING LAKE
Oct. 3
LONG SPRUCE GENERATING STATION
Sept. 27
SCALE
miles
0 5 10 15
0 5 10 15
kilometers

Figure 17: Locations of radio tagged trout 49.200 Mhz in 1987-88.

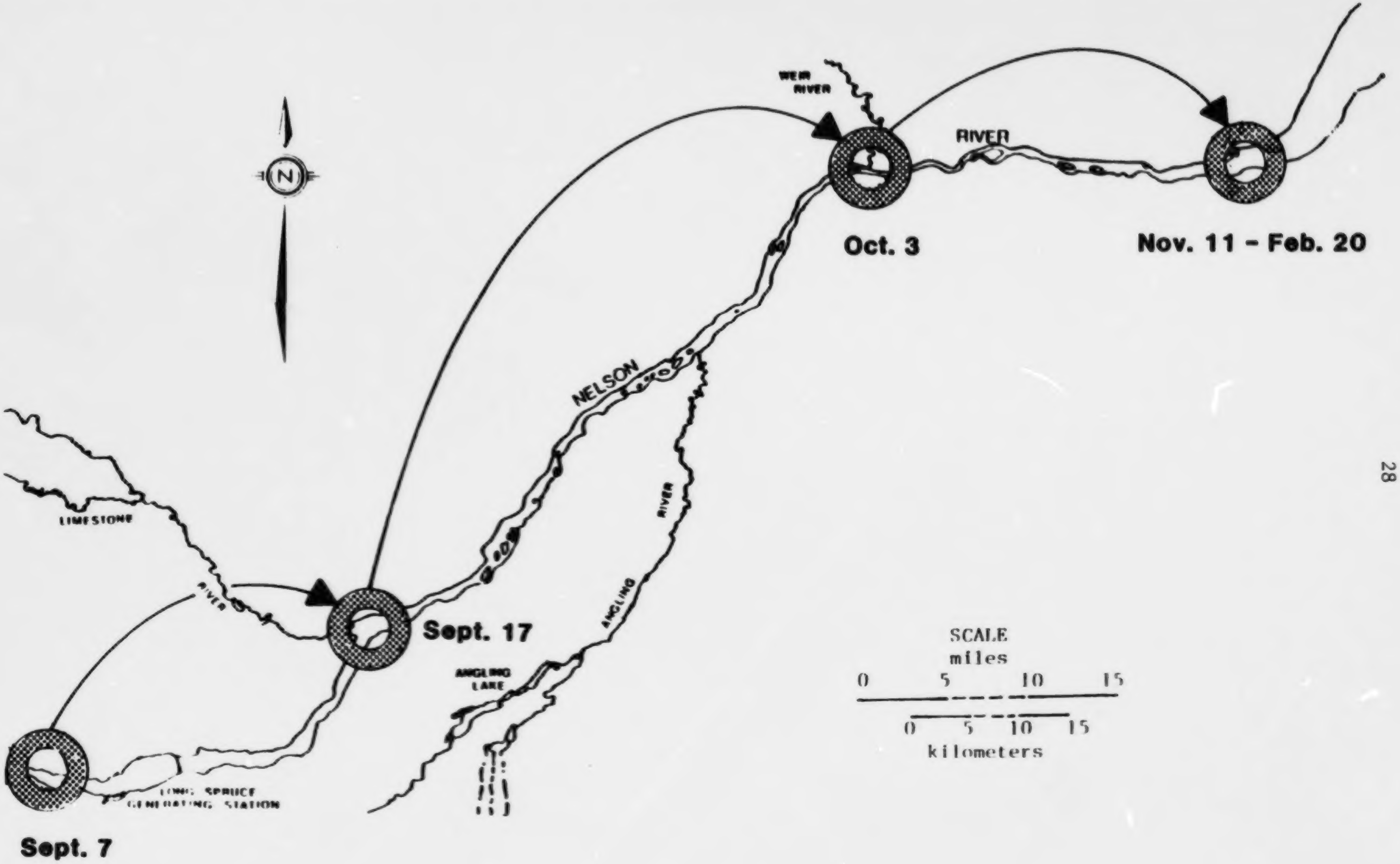

N
WEIR RIVER
RIVER
Oct. 3
Nov. 11 - Feb. 20
NELSON
LIMESTONE
RIVER
RIVER
ANGLING
Sept. 17
ANGLING LAKE
LONG SPRUCE GENERATING STATION
Sept. 7
SCALE
miles
0
5
10
15
0
5
10
15
kilometers

Figure 18: Locations of radio tagged trout 49.568 Mhz in 1987-88.

Table 2: Percent frequencies of transferred brook trout classified into "In, Out and Unknown" categories for four variable groups.

Variable	Number of Trout	Percent In	Percent Out	Percent Unknown
River of Origin				
Limestone R.	8	50.0	25.0	25.0
Weir R.	11	36.4	45.5	18.2
Stocking Location				
Reservoir	6	33.3	50.0	16.7
Kettle R. Mouth	6	33.3	33.3	33.3
Spawning Pool	7	57.1	28.6	14.3
Sex				
Male	13	46.2	30.8	23.1
Female	6	33.3	50.0	16.7
Age				
$\leq 4+$	10	50.0	30.0	20.0
$\geq 5+$	9	33.3	44.4	22.2

(Table 2) qualifications are required. No female Limestone River trout were transferred and the total number of males is double that of the females (Table 3). Thus the small sample size of females reduced the confidence about summary statistics based on movements of female brook trout when compared to male trout. Moreover, the distributions of young and old brook trout (i.e. "In" versus "Out") are opposites for Weir and Limestone River samples (Table 3). This river by river breakdown also indicates that the tendency for spawning pool trout to remain in the system was most pronounced in Weir River trout (Table 3).

Comparison of In and Out classifications was done for each of the four transfer categories (i.e., River of Origin, Stocking Location, Sex and Age) using 2xC contingency tables and the Chi-square test statistic. The null hypotheses were of independence and equality (Table 4). No statistical evidence could be inferred to indicate that movement out of the reservoir was related to any of the four variables. Consequently, both null hypotheses were accepted. Therefore, while some evidence was observed to indicate longer residency of Limestone River and spawning pool brook trout, data were not statistically significant ($\alpha < 0.05$).

Preferred winter habitat for brook trout transferred into Kettle River-Long Spruce Reservoir did not appear to be the Kettle River. In fact, of the eight trout released there and subsequently located, only 1 (49.378 Mhz; Figure 2) remained there throughout the duration of the experiment. One other trout was observed to move into the Kettle River (49.489 Mhz; Figure 12); however on the following tracking flight it was located downstream of the Long Spruce Generating Station.

Table 3: Percent frequencies of transferred brook trout classified into "In, Out and Unknown" categories for three variable groups by river.

River of Origin	Variable	Number of Trout	Percent In	Percent Out	Percent Unknown
Limestone	Stocking Location				
	- Reservoir	2	50.0	50.0	0.0
	- Kettle R. Mouth	4	50.0	0.0	50.0
	- Spawning Pool	2	50.0	50.0	0.0
Weir					
	- Reservoir	4	25.0	50.0	25.0
	- Kettle R. Mouth	2	0.0	100.0	0.0
	- Spawning Pool	5	60.0	20.0	20.0
Limestone	Sex				
	- Female	0	-	-	-
	- Male	8	50.0	25.0	25.0
	- Combined	8	50.0	25.0	25.0
Weir					
	- Female	6	33.3	50.0	16.7
	- Male	5	40.0	40.0	20.0
	- Combined	11	36.4	45.5	18.2
Limestone	Age				
	$\leq$4+	5	80.0	20.0	0.0
	$\geq$5+	3	0.0	33.3	66.7
Weir					
	$\leq$4+	5	20.0	40.0	40.0
	$\geq$5+	6	50.0	50.0	0.0

Table 4: Chi-square tests of independence and equality, for trout classified into In and Out categories. (Unknowns are eliminated from one analysis and considered equal to Out for the other).

Null Hypothesis	Variable	Unknowns Eliminated from Analyses	Unknowns Considered Out of Reservoir
Independence			
	Stocking locations; 2df (reservoir, river, river mouth)	0.82(.664)	1.06(.589)
	Sex; 1df (male, female)	0.58(.446)	0.25(.618)
	River; 1df (Limestone, Weir)	0.81(.368)	0.36(.552)
	Age; 1df ($\leq$4+,$\geq$5+)	0.53(.467)	0.55(.458)
Equality			
	Stocking locations; 2df (reservoir, river, river mouth)	0.87(.647)	1.48(.477)
	Sex; 1df (male, female)	0.60(.439)	0.74(.390)
	River; 1df (Limestone, Weir)	0.78(.377)	0.82(.359)
	Age; 1df ($\leq$4+,$\geq$5+)	0.64(.424)	0.11(.740)

Of those trout classified as having stayed in the reservoir system, final locations in and preferences for, habitat types were as follows:

Comparison Parameter	Habitat Tailrace/ Channel	 Flooded Creek Mouths	 Flooded Forebay
Final Location	2(28.6%)	3(42.3%)	2(28.6%)
Preference (Majority of Time)	1(14.3%)	5(71.4%)	1(14.3%)

Hence, preference for flooded creek mouths is indicated as reservoir overwintering habitat. It is of interest to note that of those trout classified into the In category two exhibited upstream movements into faster currents in late winter whereas two exhibited net downstream movements into the diked settling basin. Of these trout three remained in one location for 78.7% (49.350 Mhz; Figure 5), 94.1% (49.138 Mhz; Figure 6) and 70.5% (49.058 Mhz; Figure 9), of the study period.

There did appear to be a difference between Limestone and Weir River trout with respect to upstream and downstream habitat selection. The distributions were as follows:

River	Movement Upstream in Reservoir	 Downstream in Reservoir	 Downstream and out
Limestone*	3(42.9%)	2(28.6%)	2(28.6%)
Weir*	1(11.1%)	3(33.3%)	5(55.5%)

*49.178, 49.158 and 49.592 eliminated.

Chi-square test statistics for a 2x3 contingency table of habitat selection yielded values of 2.27 2df (P=.321) for the hypothesis of independence and 2.39 2df (P=.288) for the hypothesis of equality. The significance of these values were increased when the downstream groupings were pooled to 2.12 1df (P=.145) and 2.33 1df (P=.127) respectively. These are the most significant differences between any groupings studied however they still aren't considered statistically significant ($\alpha > 0.05$).

Strontium

Strontium level frequency distributions are presented for six locations sampled in 1987 and two locations sampled in 1986 (Figures 19 and 20). As can be noted very few trout with elevated strontium levels were sampled in either the Limestone Forebay (Figure 19A) or in the Limestone River and Moondance Creek area (Figure 19B and 20). In fact only 2.5% of the 121 trout sampled for strontium level assessment in Wilson and Sky Pilot Creeks combined were considered "anadromous" (Strontium >215 $\mu g \cdot g^{-1}$). In the combined Limestone River samples a total of three out of 174 brook trout greater than 150 mm F.L. (1.7%) were "anadromous".

Peak frequencies were observed in the 100-124 $\mu g \cdot g^{-1}$ strontium level range for Sky Pilot and Wilson Creeks (Figure 19A) and in the 75-99 $\mu g \cdot g^{-1}$ strontium level range for 12-Mile, 9-Mile, CN and Moondance creeks (Figure 19B and 20A). Limestone and Weir River strontium frequency distributions were spread out indicating greater anadromy (Figure 20B). On the whole the data indicates that smaller

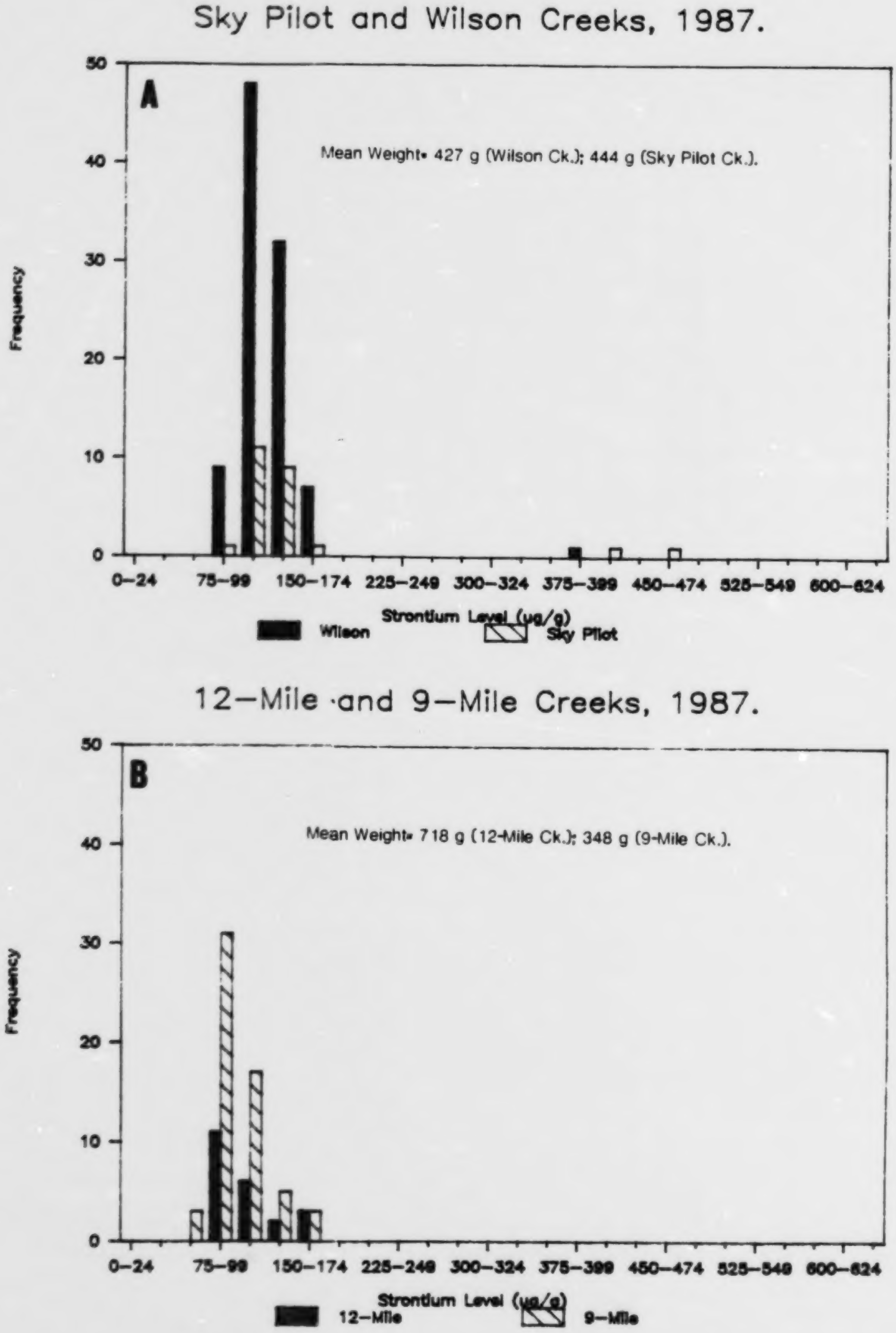
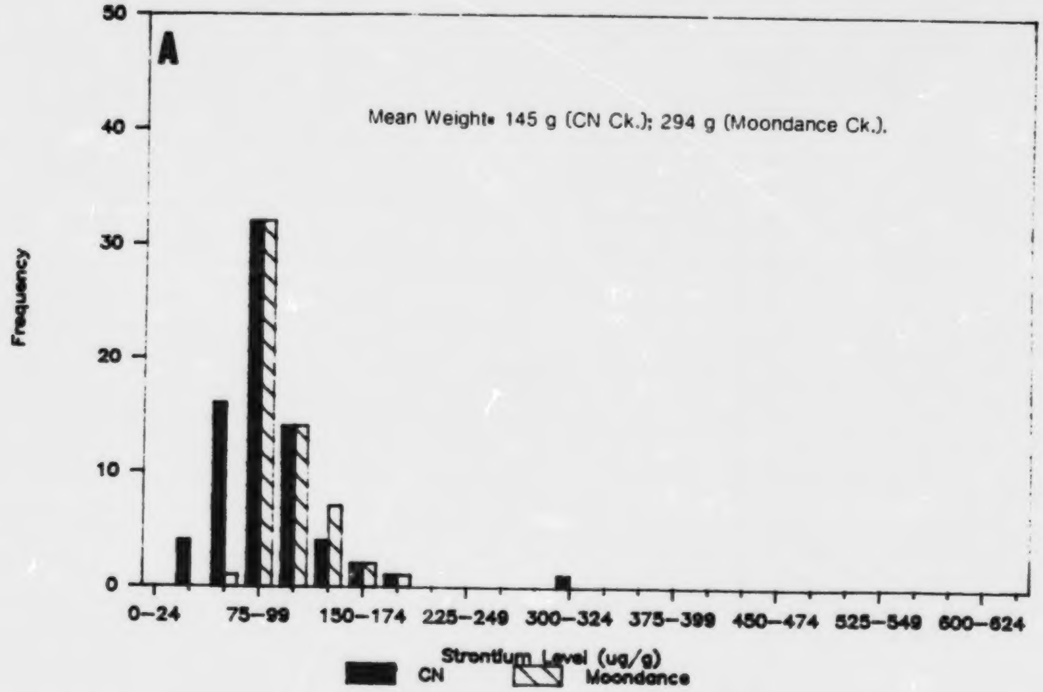
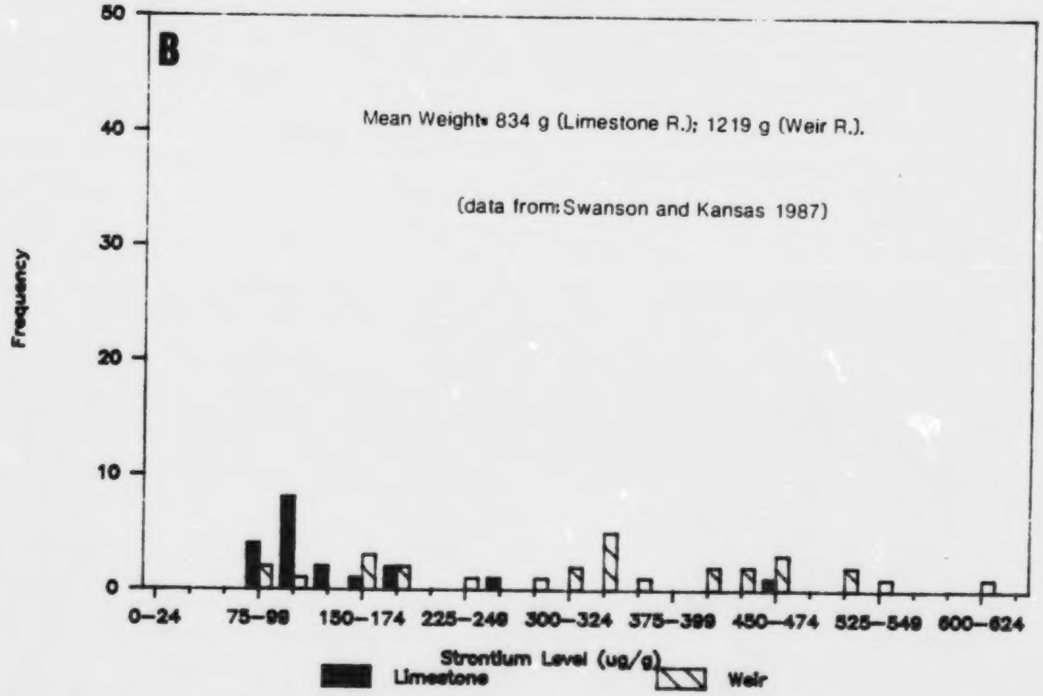


Figure 19: Strontium frequency distributions for Wilson and Sky Pilot creeks (A) and 12-Mile and 9-Mile creeks (B) in 1987.


CN and Moondance Creeks, 1987.

Mean Weight= 145 g (CN Ck.); 294 g (Moondance Ck.).


Limestone and Weir Rivers, 1986.

Mean Weight= 834 g (Limestone R.); 1219 g (Weir R.).

(data from: Swanson and Kansas 1987)

Figure 20: Strontium frequency distributions for CN and Moondance creeks in 1987 (A) and Limestone and Weir Rivers in 1986 (B).

streams have smaller trout and fewer "anadromous" trout than do larger streams.

DISCUSSION

The data presented, failed to demonstrate statistically significant responses of brook trout transferred into Long Spruce Reservoir. This is in part attributable to small sample sizes when considering the number of groups trout were categorized into. There were however trends which were observed and are discussed below.

Radio telemetry data indicated that the Kettle River was not preferred overwintering habitat for fall transferred brook trout. It is possible that water quality, decreasing water temperatures, brook trout homing tendencies, the disorienting effects of placement in a different system, or reduced spawning in the Kettle River resulted in the observed exodus of brook trout out of the Kettle River. While a number of impacts affecting water quality existed prior to 1987, the most serious of these, chlorinated sewage effluents, is not believed to have been cause for concern during the experiment. Only non-chlorinated sewage effluents were released from January, 1987 to August, 1988 (Dennis Crozier, Gillam L.G.D., pers. comm.). The next most plausible cause is that Butnau River water entering the Butnau Diversion is unsuitable for brook trout. This too is an unlikely reason as brook trout were sampled in the Kettle River prior to 1987 (Swanson 1986).

Another possibility is that brook trout exited the Kettle River after water temperatures decreased. Recent studies have indicated that rapidly decreasing water temperatures in the fall can place significant physiological stress on brook trout (Cunjak et al. 1987;

Cunjak 1988). It seems likely that the Kettle River would cool faster than the Nelson River and brook trout may have moved out of the Kettle River in response to cooling water. This theory is confounded however by the actions of one trout. Radio tagged trout 49.489 Mhz was observed to move upstream from the reservoir into the Kettle River to near the spawning pool on October 3, 1987 and then back out. This movement was in contrast to the movements of five other trout that were transferred into the Kettle River and had moved out of the Kettle River as of October 3. Moreover, two trout radio tagged in 1985 remained in the Kettle River over the winter of 1985-86 (Swanson 1986). Thus, the evidence does not support water quality and decreasing temperatures as possible explanations of brook trout avoidance of the Kettle River in the fall-winter of 1987-88.

Perhaps brook trout movements were simply a response to different surroundings. Transferred brook trout were in most cases (16 of 19 = 84%) removed in September from spawning areas in the Limestone and Weir Rivers; consequently trout were approaching or in spawning condition. While homing in brook trout is not well studied (Power 1980) and migration is not believed to be as developed as in more specialized migrators (i.e. Onchorynchus and Salmo spp.) (McCormick and Naiman 1984a; 1984b) annual spawning in specific spawning areas has been documented in Nelson River stocks (Gaboury 1980), and homing of displaced brook trout was reported to be high in Matamek Lake Quebec (O'Connor and Power 1973). It is therefore possible that upon transfer into the Kettle River and encountering an unfamiliar water chemistry brook trout either selected to leave the Kettle River or passively drifted out of the system. It is also possible that reduced or absent spawning and recruitment in the Kettle River facilitated this disorientation. Previous authors have labelled the by-products of juvenile arctic char (Salvelinus alpinus) existence, specifically char bile enzymes, as the odoriferous cue stimulating upstream movements of mature arctic char (Doving et al. 1973; Selset and Doving 1980; and Doving et al. 1980). Perhaps the reduced levels of juvenile brook charr in the Kettle River functioned to reduce the perceived suitability of the Kettle River to mature brook trout in spawning condition.

The combination of general disorientation and the exacerbating effects of spawning condition and homing tendencies are the most attractive explanations for movement out of the Kettle River. These reasons may explain why the percent of transferred trout (charr) that moved out of the system decreased with stocking location distance upstream on the Kettle River (Table 2). Perhaps the farther upstream on the Kettle River the trout were transplanted the more opportunity was provided for acclimating to the river-reservoir system (i.e. time and space). The implications of this are that future trout transfers should take place in spring (reduced spawning interference) and stocking should be as far upstream as is feasible.

Selection of habitat within the reservoir was primarily for flooded creek mouths. A majority of the seven trout known to have remained in the reservoir seemed to prefer flooded creek mouths for overwintering in (5 of 9 = 71.4%). Perhaps reduced currents and increased feeding opportunities are afforded to brook trout in these areas during the physiologically stressful winter months (as discussed previously; Cunjak et al. 1987; Cunjak 1988). This overwintering strategy is similar to that demonstrated by radio tagged brook trout in the unimpounded Limestone River (Swanson 1986; Swanson and Kansas 1987). In these studies brook trout were most often located at creek mouths entering into larger rivers. The theory of winter stress is however confounded by upstream movements. Two trout moved upstream into faster tailrace/channel habitat in late winter (49.380 Mhz; Figure 10 and 49.310 Mhz; Figure 11). Temperatures and therefore feeding should have been consistently low during this period and the reasons for upstream movements are uknown.

The implication of the radio telemetry forebay use information is that inundated creek mouth habitat is preferred overwintering habitat for brook trout. Consequently as diverse a habitat as possible in flooded creek mouths will provide the best combination of cover and reduced velocities for overwintering brook trout. This translates into a no-clearing policy for flooded creek mouths to maintain reservoir trout habitat. Moreover, the presence of standing timber may increase invertebrate production (Baxter 1977). This may be particulary true for creek mouths where stream flow brings nutrients and allocthonous drift. This may lead to increased feeding opportunities for brook trout. For these reasons, leaving standing timber in creek mouths to be flooded upon impoundments, is the preferred clearing policy (i.e. zero clearing in creek mouths).

The radio telemetry information supports previous predictions that some brook trout would move out of a newly impounded reservoir and some would remain within (Swanson 1986; Swanson and Kansas 1987). As noted in Figures 2-18, seven of the 14 radio tags consistently located throughout the study period moved out of the reservoir while seven remained in. This follows to some extent the data collected in unimpounded Limestone River radio telemetry studies in 1985-86 and 1986-87 (Swanson 1986; Swanson and Kansas 1987). In these studies a combined average of 83.3% of those trout tagged in the Limestone River overwintered in the Limestone River. By comparison 66.7% of the Limestone River trout transplanted and tracked consistently (n=6) remained in the Long Spruce Reservoir in 1987-88. As stated previously disorientation may have functioned to limit their use of the Kettle River.

The fact that only 37.5% of the Weir River radio tagged trout consistently located (n=8) remained in the reservoir compared to 66.7% of Limestone River trout may be linked to the relative status of the stocks. Because Weir River stocks are in better shape (less exploited) intraspecific competition for overwintering habitat is high and trout may move greater distances in response to this. Perhaps increased movements in Weir River stocks are a behavioural response to increased stock size. It is also possible that the Weir River is consistently more shallow and has less overwintering habitat than the Limestone River. Therefore, downstream movements of Weir River trout may be a learned response which manifested itself in more Weir River trout moving downstream and out of the reservoir in the fall.

Current Limestone River and Limestone Forebay brook trout stocks are not to be considered anadromous. In fact of the trout sampled in 1987 that were greater than 150 mm fork length (FL) only 2.1%

(6 of 291) had strontium levels greater than 215 $\mu g \cdot g^{-1}$ of fin ray. The 150 mm FL minimum size criteria is based on studies which documented the poor survival of brook trout smaller than this in seawater (McCormick and Naiman 1984b). A strontium based anadromy level of 215 $\mu g \cdot g^{-1}$ of fin ray was used based on the characteristics of the strontium level frequency distributions (Swanson 1986; Swanson and Kansas 1987). This level is supported by strontium level determinations on arctic char from Cambridge Bay (Swanson and Kansas 1987) and arctic char from Devon, Cornwallis and Baffin Islands, Northwest Territories where strontium levels in land-locked populations were as high as 200 $\mu g \cdot g^{-1}$ and sea run population levels were in the 200-500 $\mu g \cdot g^{-1}$ range (Stewart and MacDonald 1981). The low level of anadromy currently observed (2.0% overall) is not however, meant to infer that anadromy was always this low.

The role of anadromy in brook trout life history is facultative rather than obligatory. McCormick and Naiman (1984a; 1984b) and McCormick et al. (1985) argue that based on reduced levels of osmoregulating physiological change during pre-saltwater existence, brook trout acclimate to saltwater rather than adapt beforehand. In fact, McCormick et al. (1985) assert that smoltification is undeveloped in brook trout compared to Atlantic salmon (Salmo salar). As a consequence, it can be argued that while brook trout can tolerate a saltwater existence, increased fall and spring plasma thyroxine levels in brook trout exert their influence through increased growth, appetite or activity rather than through smoltification (McCormick and Naiman 1984a). Thorpe (1987) argues that anadromy in salmonids in general is an adaptation to poor growth and the conditions which foster poor growth (i.e small, cool, unproductive streams). In fact Thorpe (1987) states that fast growth and anadromy are physiologically mutually exclusive. Nelson River brook trout growth is at one of the fastest rates in North America (Gaboury 1978). Moreover, the heavy exploitation as documented by Gaboury (1978; 1980) and as illustrated by the reduced sizes of brook trout present, (Appendix 1) means that intraspecific competition is reduced and growth should be approaching its maximum. Thus Limestone River and Limestone Forebay anadromy may be reduced via the removal of intraspecific competitions through angler harvest and the associated faster growth rate. Consequently, strict comparison of Limestone River and Weir River anadromy levels is not proper. Given reduced exploitation levels and increased stock strengths the level of anadromy in the Limestone River might be higher. In fact if proximity to the sea is proportional to the level of anadromy (Swanson and Kansas 1987), and brook trout migrations are opportunistic in nature (McCormick and Naiman 1984a; 1984b) then the fact that the Weir River is approximately three times closer to Hudson Bay means that 5-Mile Hole (Limestone River) anadromy levels may have been as high as 24%; i.e. Weir River level (72%) ÷ 3 = 24%, when exploitation on the Limestone River was similar to what it is now at the Weir River.

CONCLUSIONS

1. A total of 50% of the trout transferred into Long Spruce Reservoir and consistently tracked thereafter remained in the Kettle River-Long Spruce Reservoir system. This means that brook trout are capable of overwintering in a reservoir.
2. Disorientation magnified by trout spawning condition is hypothesized to have exerted the largest influence on radio tagged brook trout exiting the Kettle River-Long Spruce Reservoir System.
3. Overwintering habitat preference within the reservoir appears to be inundated creek mouths.
4. Currently, Limestone River/Limestone Forebay stocks are ∿2% anadromous.
5. Historically, anadromy may have been more common in Limestone River brook trout, perhaps reaching as high as 24% occurrence.

RECOMMENDATIONS

1. Given the opportunistic nature of brook trout movements, and the decreased significance of anadromy and the fact that some trout will remain upstream of future hydro electric generating stations regardless, a fish ladder at Conawapa for brook trout is not recommended.
2. Spring transfers of radio tagged brook trout into the Kettle River-Long Spruce Reservoir should take place in 1988 to provide additional data on river and reservoir suitability to brook trout. Information will also assess the probability of rehabilitating stocks via adult trout transfers.
3. Forebay clearing policies should leave standing timber in flooded creek mouths as cover for brook trout and to increase fish production in an otherwise inhospitable reservoir.

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TRIBUTARY STUDY

INTRODUCTION

Small tributaries of the Nelson River (drainage areas $<150\ km^2$) serve as nursery areas for immature brook trout (Gaboury and Spence 1981; Swanson 1986; Swanson and Kansas 1987). The mechanisms by which these juvenile and young of the year (y.o.y.) brook trout come to inhabit many of these tributaries has not as yet been determined. While production for two small tributaries has been estimated at roughly $5.5\ kg\ ha^{-1}\ yr^{-1}$ (Gaboury 1980), seasonal use, immigration and emigration of immature brook trout and early life history information in general for brook trout in the lower Nelson River is lacking. In an attempt to assess the contribution of these streams to Nelson River brook trout stocks three tributaries of the lower Nelson River were monitored through the open water season of 1987. (i.e. CN/Gravel Pit Creek, Moondance Creek and an unnamed tributary--"Beaver Creek").

Information which was to be garnered was of first order management importance. Potential impacts of Manitoba Hydro's Limestone and Conawapa Generating Stations are focused on the south shore of the Nelson River near Moondance Creek (borrow areas) and along the north shore of the proposed Conawapa Forebay (permanent Conawapa access road and numerous borrow areas). Data collected which reflect life history strategies and therefore sensitive habitat will applied to recommendations regarding stream crossing and borrow pit work permit conditions.

METHODS

Physical Parameters

Stream temperature was measured daily using a hand held thermometer (± .5°C) at two way fish fences. Discharges were estimated using stage: discharge relationships established for each of the three study streams (Appendix 2). Four discharge measurements were collected during the open water season to establish the relationship with stage. Stage was measured daily from staff gauges installed in a small pool on each creek. Groundwater was sampled on CN Creek by measuring intrasubstrate water temperatures with an electronic thermometer and a stainless steel encased thermocouple.

General

All brook trout sampled had their fork length (FL) measured to the nearest millimeter. Scale samples from above the lateral line and below the dorsal fin were collected from trout 150 mm FL. These trout were weighed using a hand held scale (± 50 g) and Floy tagged as per Swanson (1986). Trout smaller than 150 mm FL had their total volume measured by displacing water in a two liter graduated cylinder. Weights for these trout were estimated by applying 1 gram to every milliliter displaced (Price 1982).

Brook Trout Movements

To monitor emigration of brook trout fry from the study streams, river drift samplers, after Burton and Flannagan (1976), were used at two sites on each creek. Drift samplers were cleaned daily and fish samples were sorted and preserved in 10% formalin. Drift samples were collected from as soon after ice off as was possible (i.e. May 12) until June 10 (after drift was over).

To monitor immigration and emigration of larger y.o.y. and juvenile brook trout, two way fish fences were installed as close to the mouth of each tributary as was possible. These fences were sampled from May 14 to October 14, 1987. Additionally, a temporary fence (fence 2) was installed closer to the mouth of CN Creek and was sampled daily from July 23 to September 22, 1987. Traps were sampled and fences were cleaned and repaired on a daily basis. Trout were released into pools on the opposite side of the fence to which they were sampled on. Locations of drift samplers and fences are presented in Figure 1.

Brook trout in upstream pools were sampled by angling and seining. All trout captured were sampled, tagged and released. All subsequent recapture information was recorded and movements were summarized.

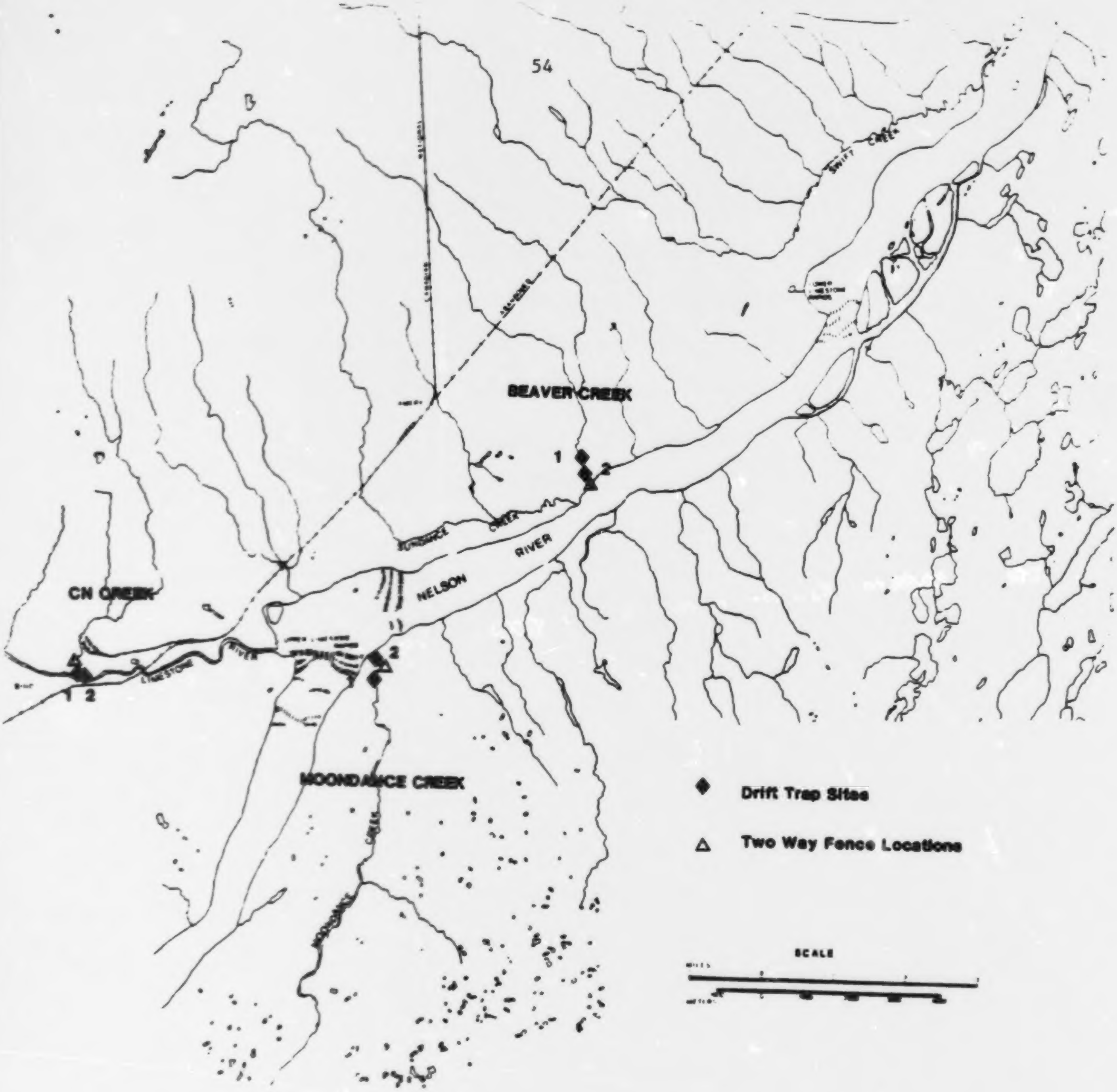

BEAVER CREEK
1
2
CN CREEK
1 2
LIMESTONE RIVER
SUNDANCE CREEK
NELSON RIVER
SWIFT CREEK
2
MOONDANCE CREEK
MOONDANCE CREEK
◆ Drift Trap Sites
△ Two Way Fence Locations
SCALE

Figure 1: Larval drift sampling and two way fish fence sampling locations for CN, Moondance and Beaver Creeks in 1987.

Brook Trout Utilization

Exploitation of stream habitat by brook trout was assessed using the standard electrofishing sections established on Moondance and Beaver Creeks in 1986 (Swanson and Kansas 1987) (Figure 2). Three additional electrofishing sections of 100 m each were also established on CN Creek in 1987. Physical habitat parameters were sampled as in 1986 with the exclusion of measuring stream gradient. Electrofishing entailed three complete sweeps of each 100 m section to a seine at the bottom of each section. All brook trout captured were sampled and released.

When possible, the removal method of estimating y.o.y. trout abundance was used (Zippin 1956). Additionally two single census mark-recapture experiments were carried out between the two fences on CN Creek. Abundances were estimated using modified Petersen estimates for each census and a modified Schnabel estimate for the two experiments combined (Ricker 1975).

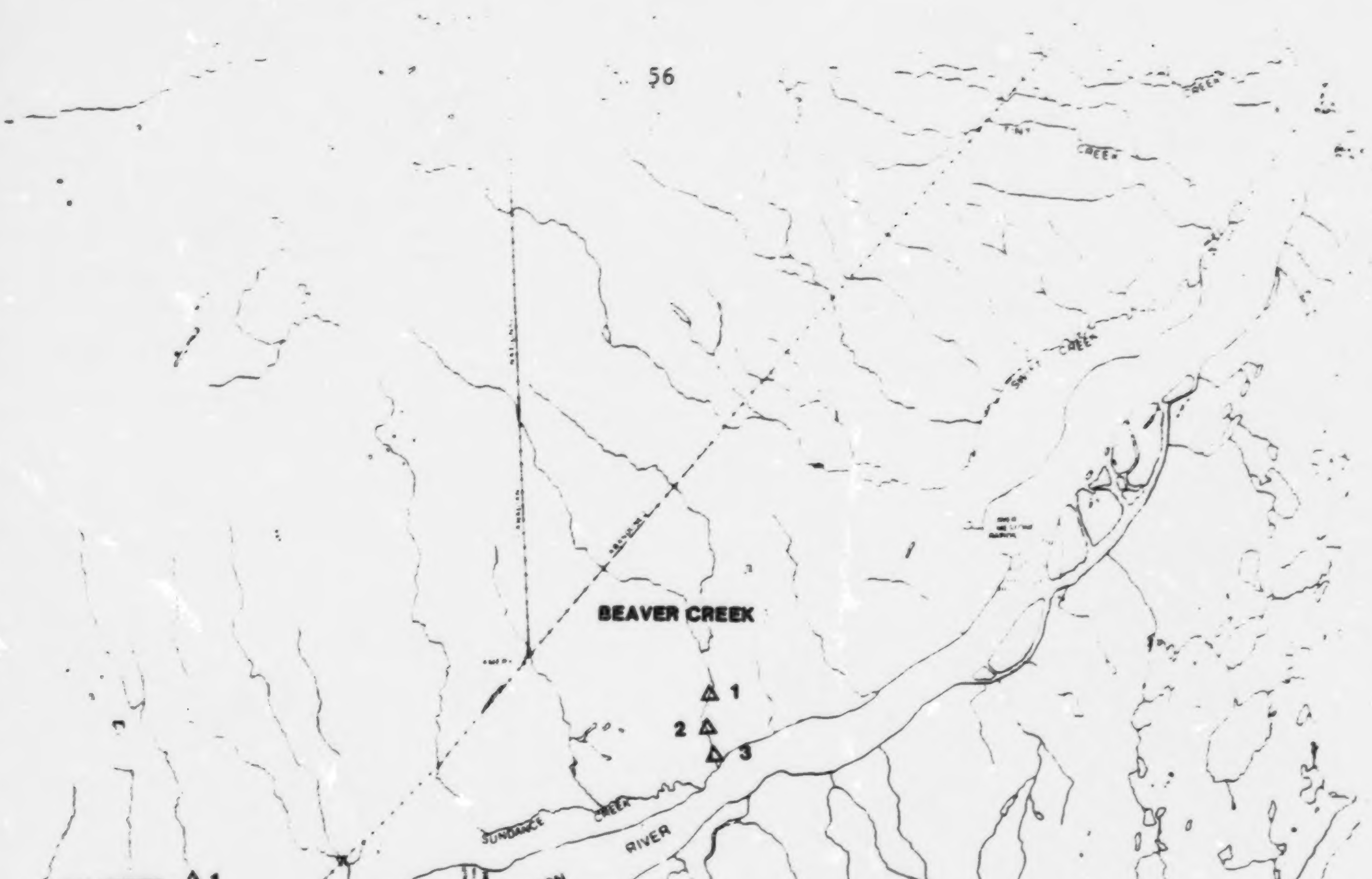

BEAVER CREEK
1
2
3
SUNDANCE CREEK
NELSON RIVER
CN CREEK
1
2
3
LIMESTONE RIVER
3
2
1
MOONDANCE CREEK
MOONDANCE CREEK
TINY CREEK
SALT CREEK
△ Electrofishing Stations
SCALE

Figure 2: Electrofishing sections for the three study streams in 1987.

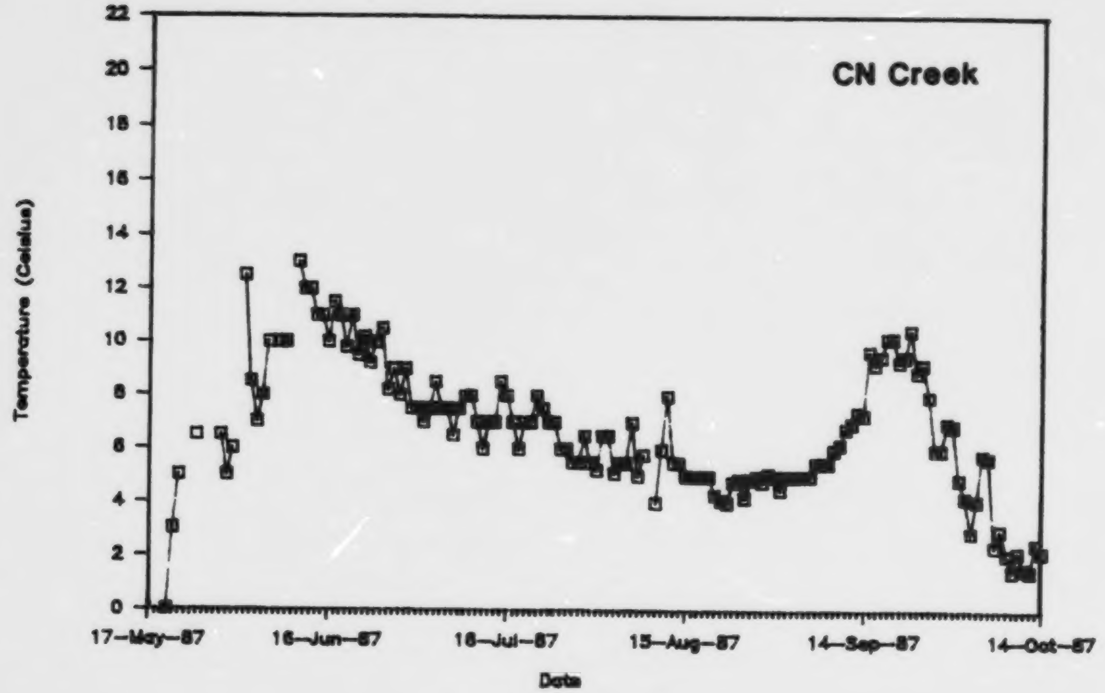
RESULTS

Physical Parameters

Temperature regimes and openwater hydrographs for CN, Moondance and Beaver Creeks are presented in Figures 3-5. Typically stream temperatures rose as flows reduced in the summer. Peak temperatures were 20.5°C, 17°C and 13°C on Moondance, Beaver and CN Creeks respectively. Spring and fall discharge peaks were generally accompanied by rising and falling water temperatures respectively.Of interest is the fact that CN Creek water temperatures were in the order of 7 - 12°C lower than those in Beaver and Moondance Creeks for most of the summer. Moreover when discharge dropped in CN Creek in midsummer to almost negligible flows, water temperature decreased rather than increasing. This indicates the presence of cold groundwater and is supported by intrasubstrate water temperature measurements which located several groundwater sites (Table 1). The distribution of 11 groundwater sites is given in Figure 6. Groundwater was not as dominant in Moondance and Beaver Creeks.

Flow rates greater than 1.1 cms in late September on CN Creek are misleading due to the backwater effect of a large debris dam which formed below the staff gauge pool at this time. Discharge on CN Creek did however increase significantly as the stream temperature was warmed by roughly 5°C due to relatively warm precipitation (ie. warmer than the groundwater). Moondance and Beaver Creeks hydrographs indicated discharge peaks in spring and fall with small summer peaks related to rainfall (Figures 3-5).

TEMPERATURE



DISCHARGE

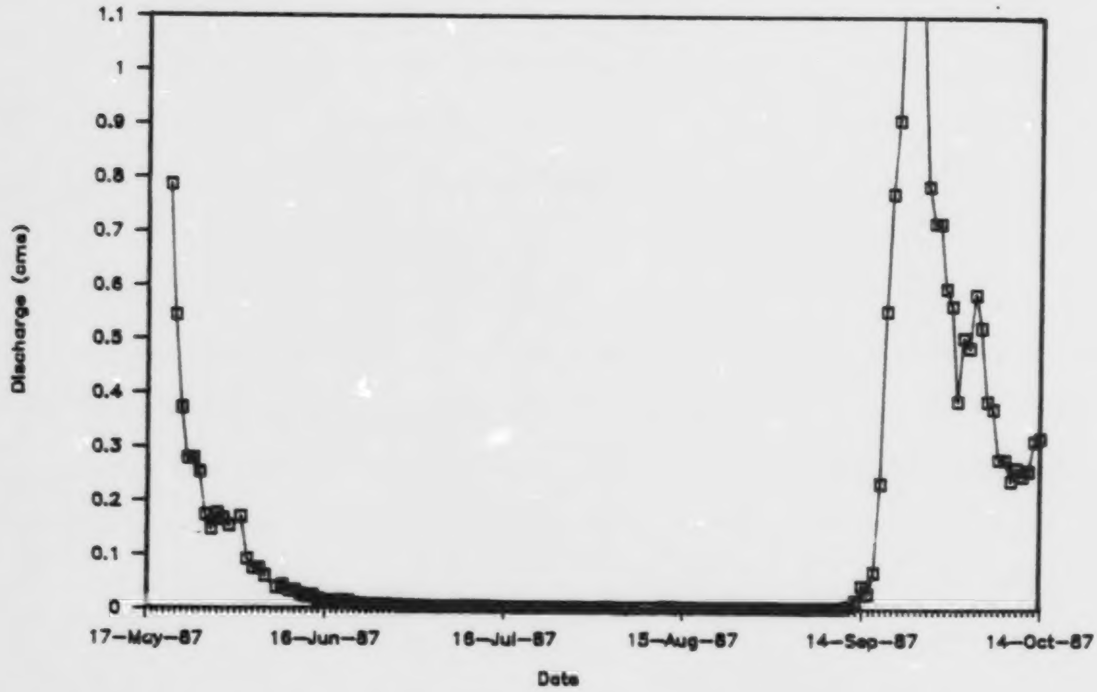
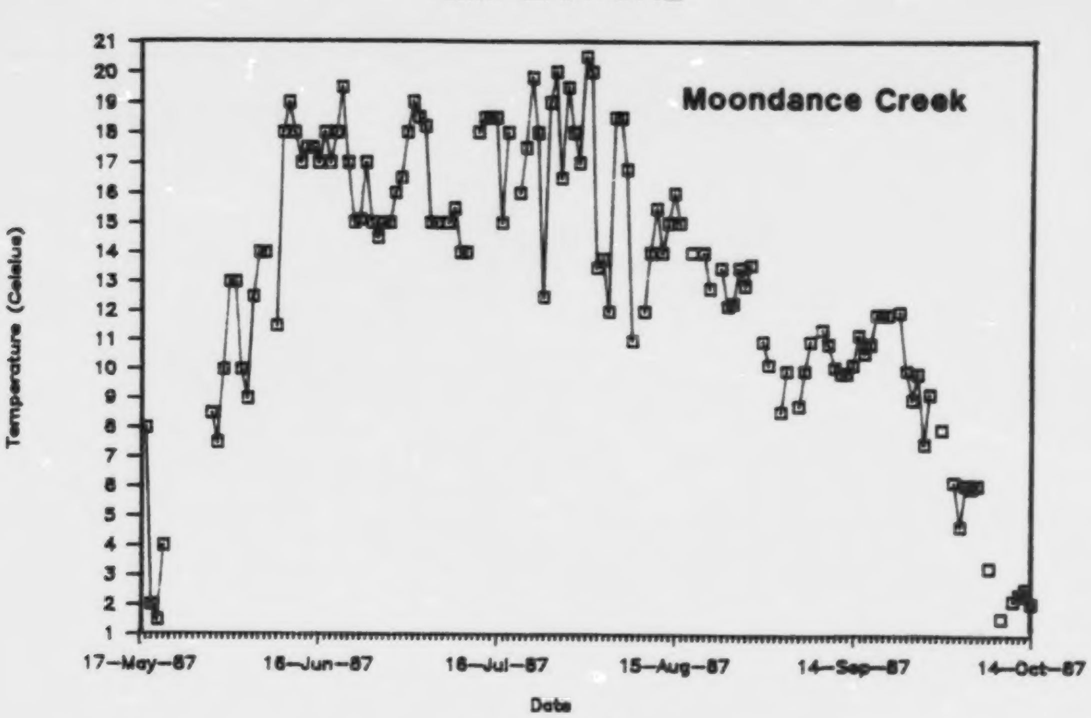


Figure 3: Openwater thermal regime and hydrograph for CN Creek in 1987.



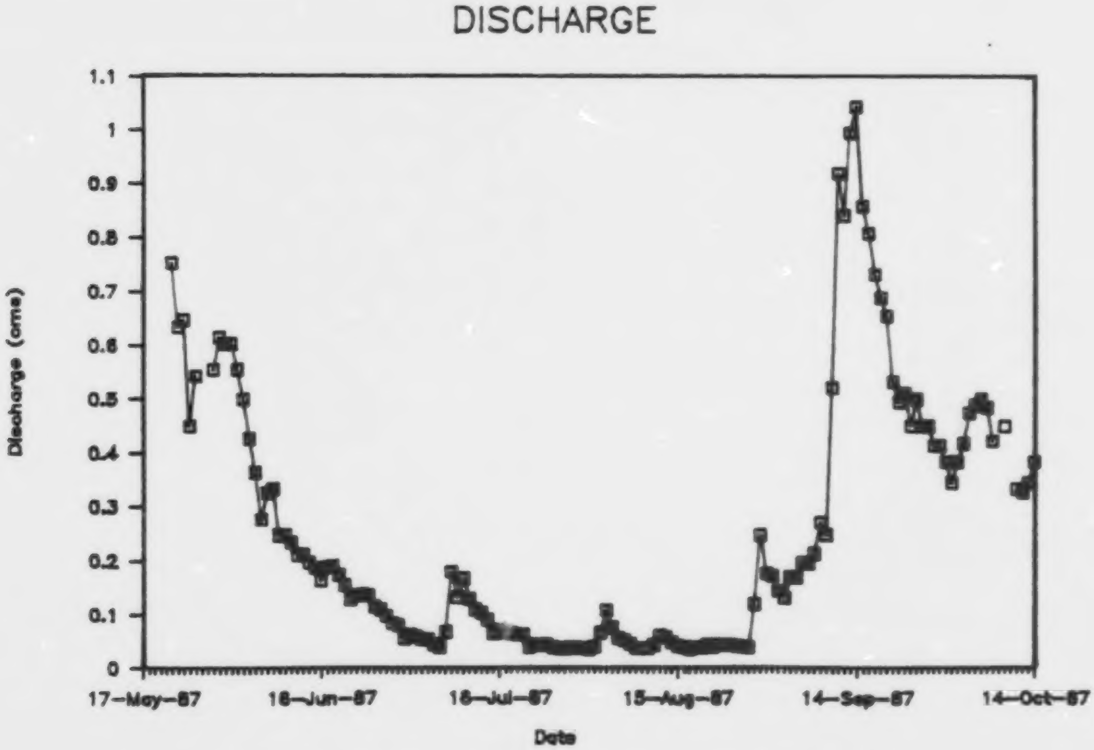


Figure 4: Openwater thermal regime and hydrograph for Moondance Creek in 1987.

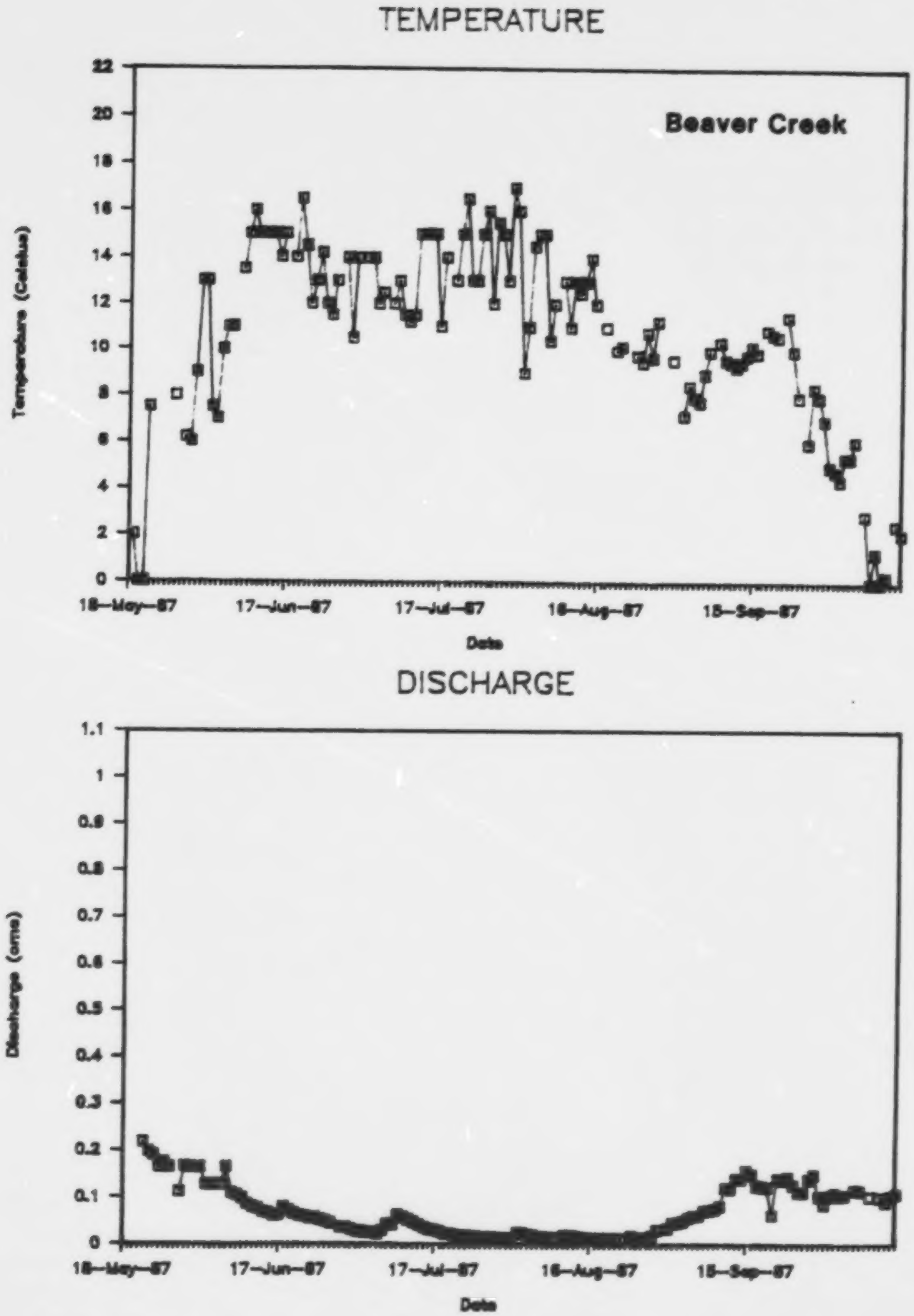


Figure 5: Openwater thermal regime and hydrograph for Beaver Creek in 1987.

Table 1: Ambient stream temperatures and site specific water temperatures at identified groundwater sites on CN Creek 1987.

Date	Groundwater Site	Ambient Stream Temperature (°C)	Surface Temperature (°C)	Intrasubstrate Temperature (°C)
07/21/87	1	11.0	5.1	4.3
	2	11.0	8.8	4.8
	3	13.0	4.9	4.8
	4	13.0	12.3	5.2
	5	13.0	5.3	5.3
	6	13.0	12.1	4.0
07/22/87	7	11.0	9.2	5.2
	8	9.0	7.8	4.5
	9	7.6	5.6	4.4
	10	7.6	7.6	3.8
	11	7.7	7.6	4.6

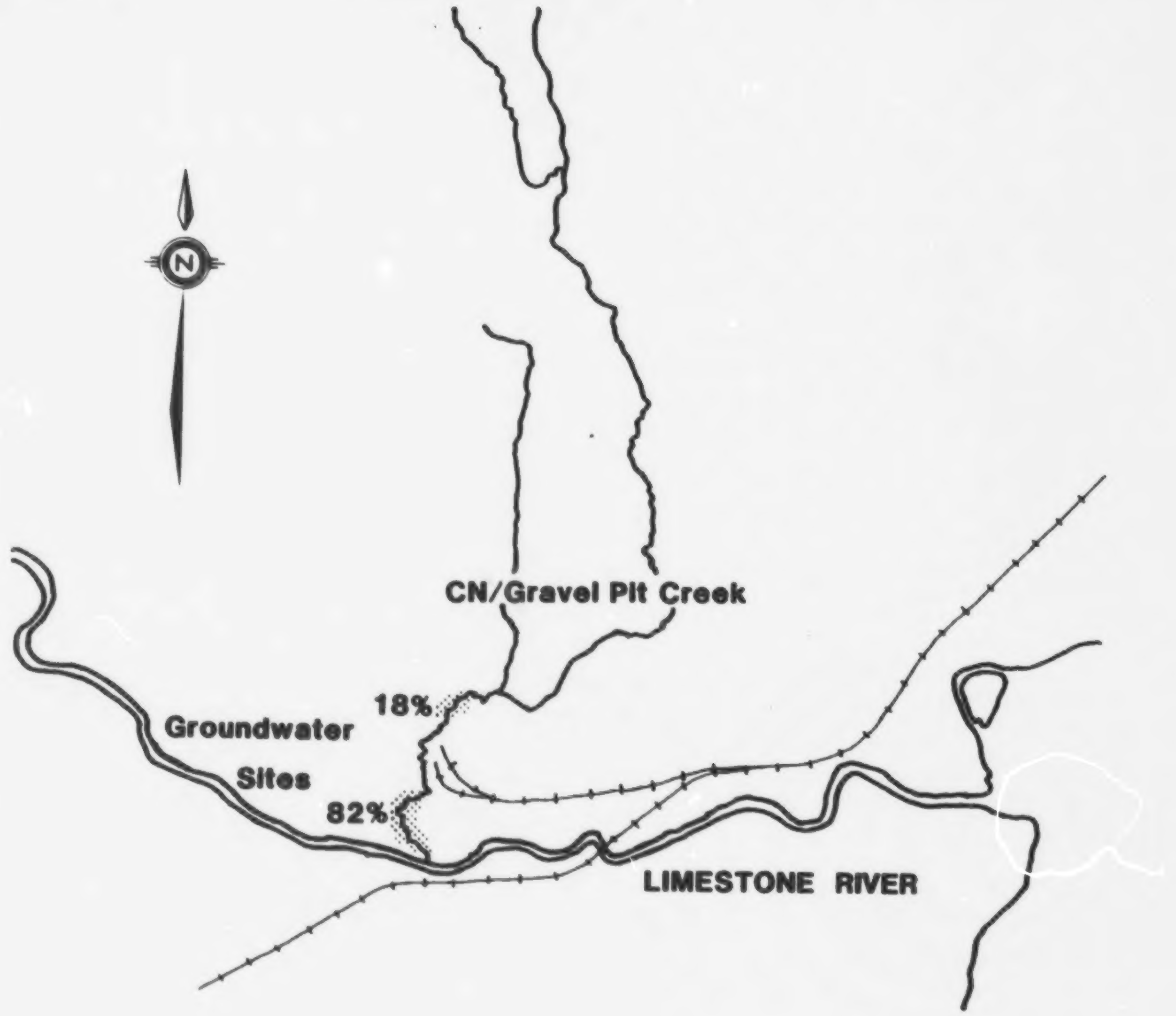

N
CN/Gravel Pit Creek
18%
Groundwater
Sites
82%
LIMESTONE RIVER

Figure 6: Approximate locations and relative abundance of groundwater upwelling sites on CN Creek in 1987.

General

A total of 827 brook trout ranging from 0^+ to 5^+ years old were sampled in CN, Moondance and Beaver Creeks using all methods combined. Tabulation of capture frequencies by creek, capture method and age is presented in Table 2. About three percent of the total sample was not aged because insufficient scales were collected or the scales sampled were not of sufficient quality to be aged.

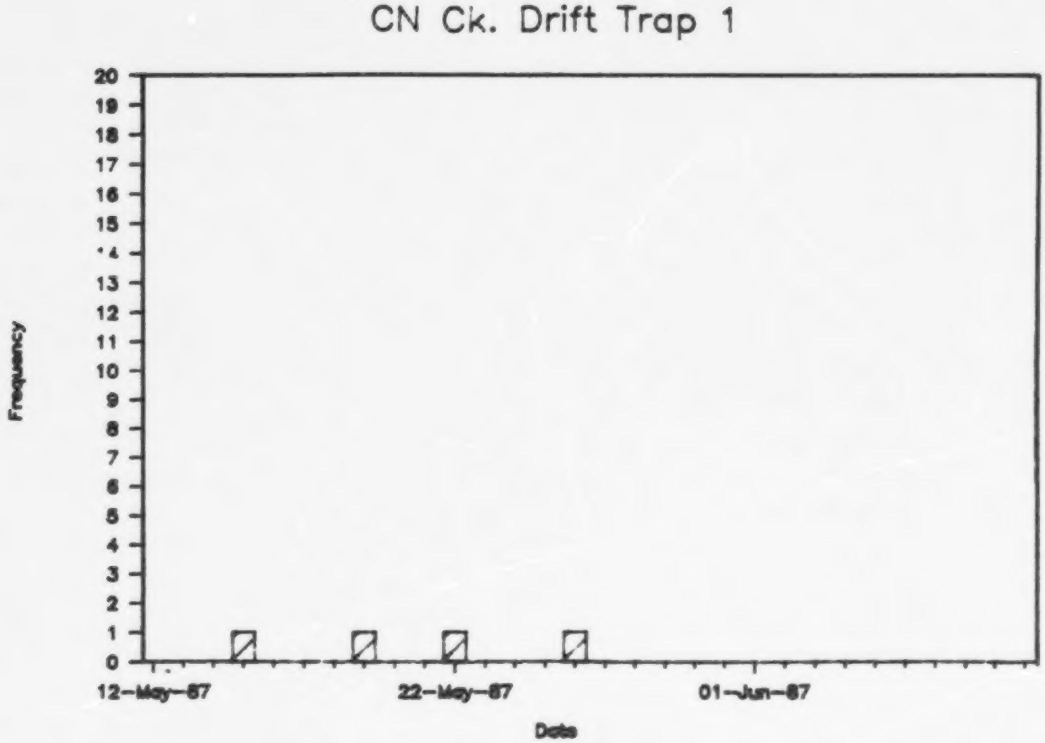
Brook Trout Movements

Larval brook trout were sampled in Moondance and CN Creeks while none were sampled in Beaver Creek. A total of 50 brook trout were sampled in CN Creek traps 1 and 2 (Figure 7). Of interest is the fact that 46 trout were sampled at the downstream location (trap 2) and only four were sampled upstream. Only 1 larval brook trout was sampled in Moondance trap 1 and none were sampled in Moondance trap 2 (Figure 8). The fact that Beaver Creek drift sampler 2 sampled a visually estimated 60% of the total flow without capturing any larval brook trout emphasizes the absence of larval brook trout in Beaver Creek "drift".

The movements of larger brook trout (30 mm FL minimum size) were seasonal in occurrence (Figures 9-11). The frequency distributions of brook trout sampled in five of six traps for the openwater season were negatively binomial indicating that groups of brook trout tended to move into traps together (Table 3). The one trap indicating random

Table 2: Age:frequency summary for brook trout sampled in CN, Moondance and Beaver Creeks, 1987.

Creek & Methods	0+	1+	2+	3+	4+	5+	Unknown
CN Creek							
Drift Trap 1	4						
Drift Trap 2	46						
Fence 1 up	35	15	4	3	1		6
Fence 1 down	13	18	3	1			5
Fence 2 up	109	1	1				
Fence 2 down	22						
Angling/seining		10	33	12	1		
Electrofishing	265	17	4				2
Section 1							
Section 2	1	2					
Section 3	3	1	2				
Total	499	64	47	15	2	0	14
Moondance Creek							
Drift Trap 1							
Drift Trap 2	1						
Fence up	3	9	19	14	9	3	7
Fence down	7		2	1			2
Angling/seining		2	10	3	1		2
Section 1	2						
Section 2	27						
Section 3	7	2	1				1
Section 4	5						
Total	52	16	32	18	10	3	12
Beaver Creek							
Drift Trap 1							
Drift Trap 2							
Fence up	23						
Fence down	9	1					
Section 1							
Section 2	1						
Section 3	2	2					2
Total	35	3					2



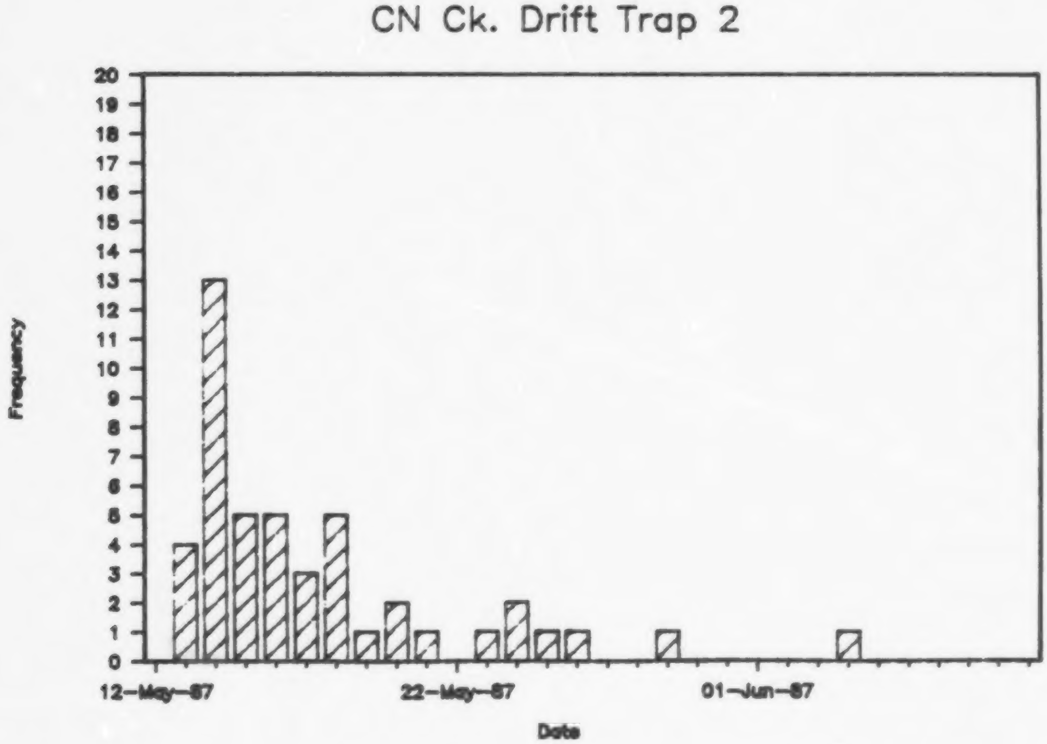


Figure 7: Larval brook trout drift frequencies for 1987.

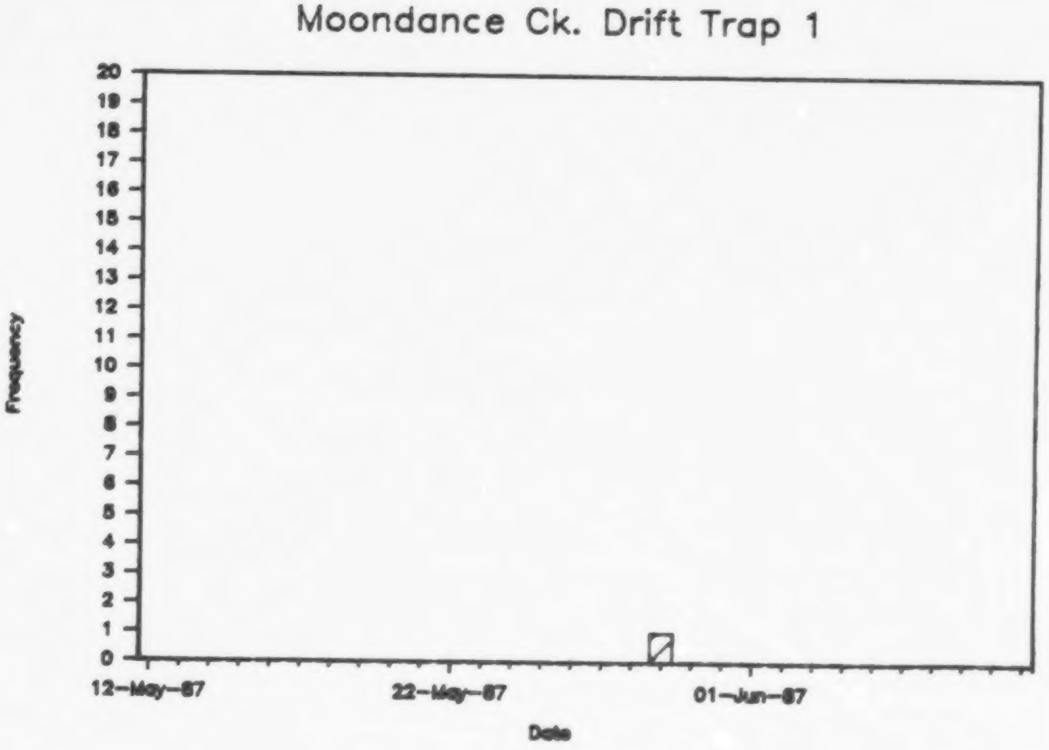
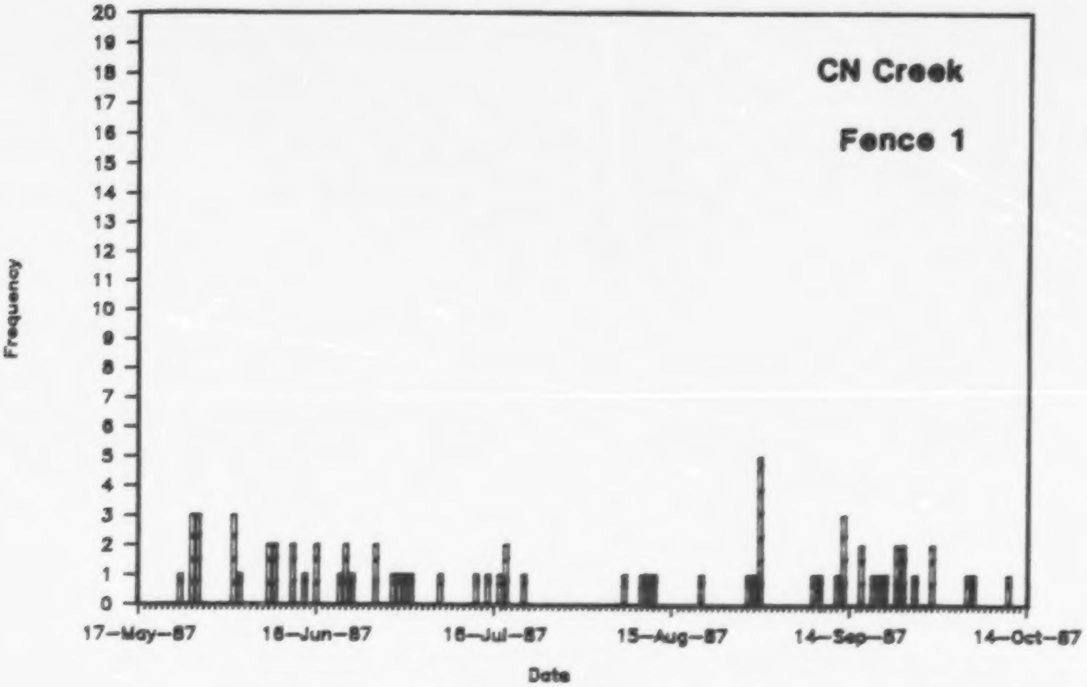


Figure 8: Larval brook trout drift frequencies for 1987.


NUMBER OF B.TROUT MOVING UPSTREAM

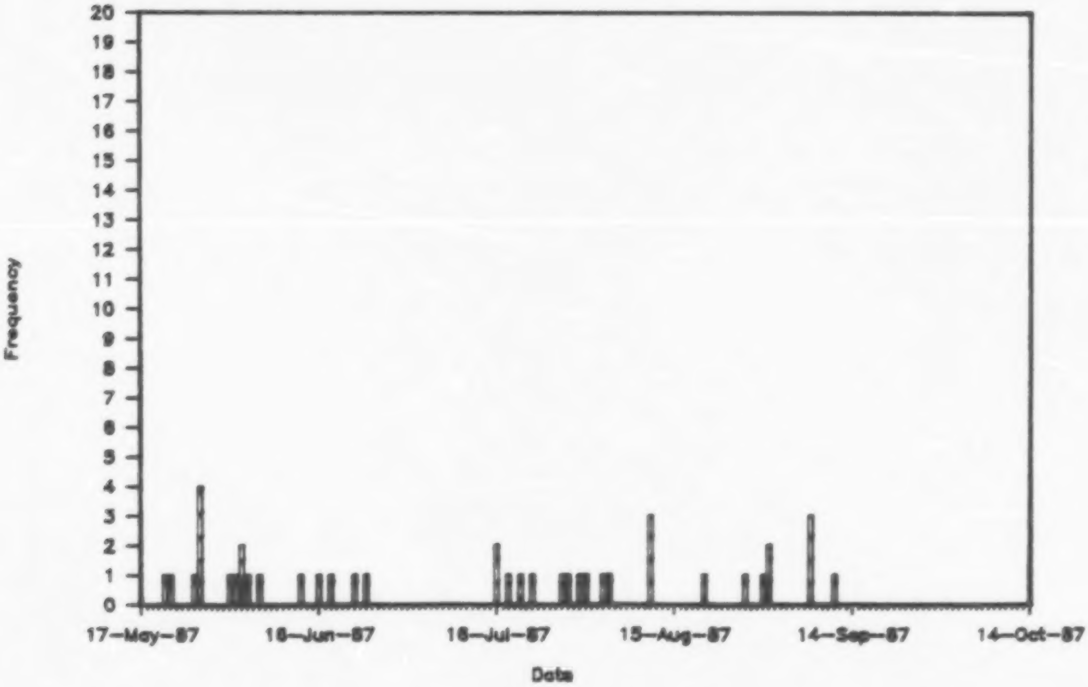
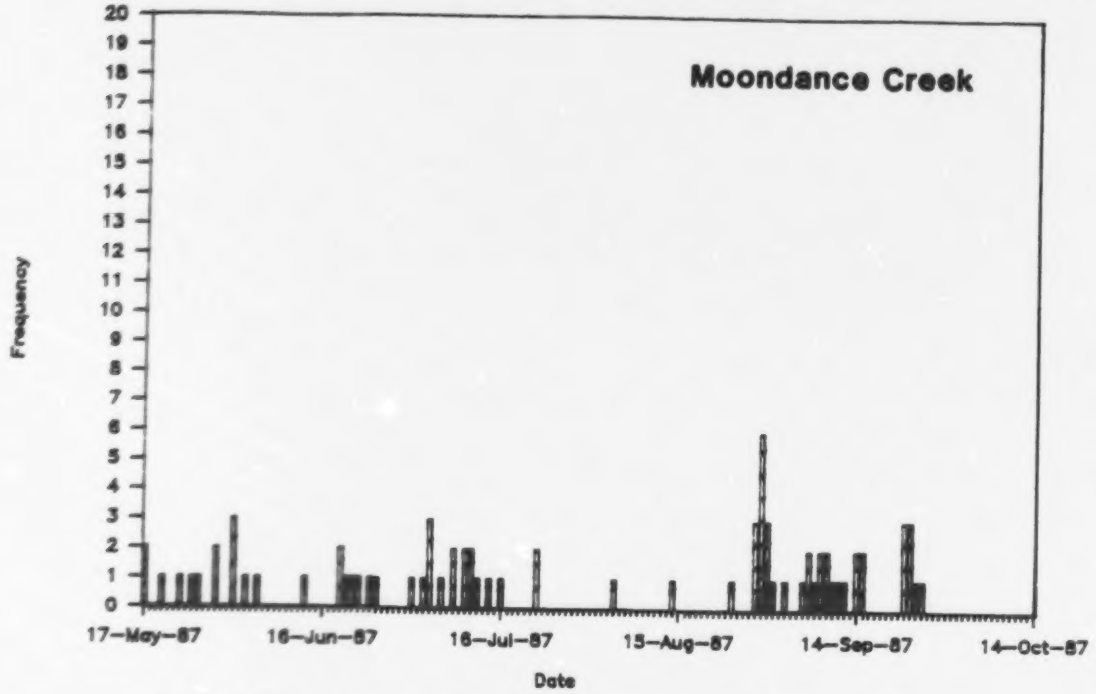

NUMBER OF B.TROUT MOVING DOWNSTREAM

Figure 9: Frequency distributions for brook trout sampled moving upstream and downstream in CN Creek in 1987.

NUMBER OF B. TROUT MOVING UPSTREAM



NUMBER OF B. TROUT MOVING DOWNSTREAM

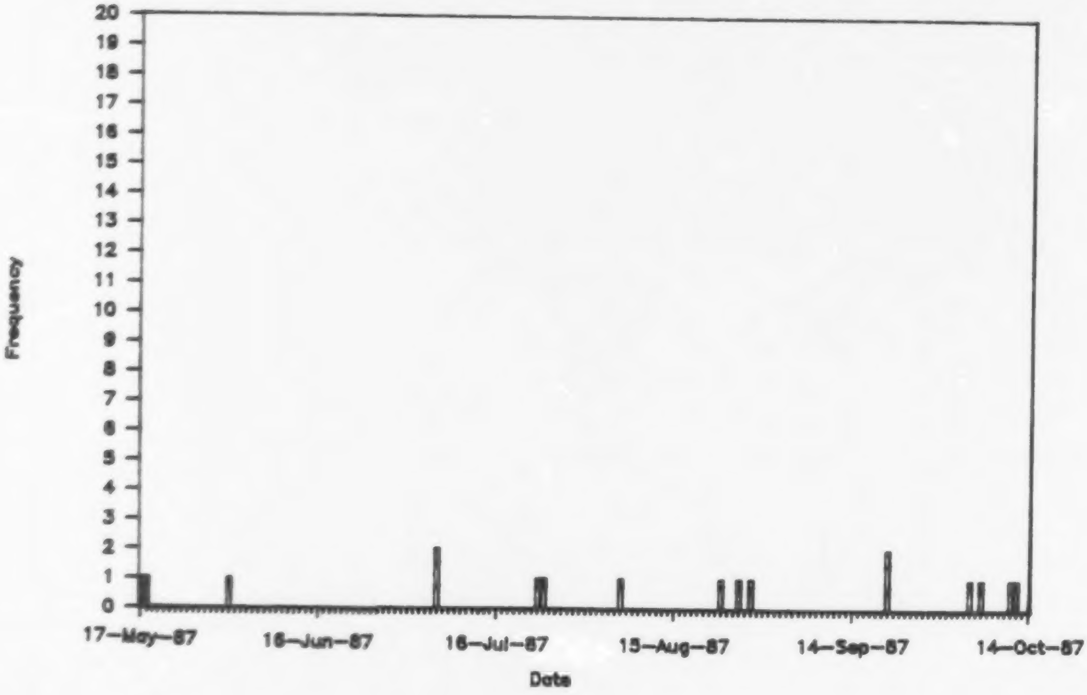


Figure 10: Frequency distributions for brook trout sampled moving upstream and downstream in Moondance Creek in 1987.

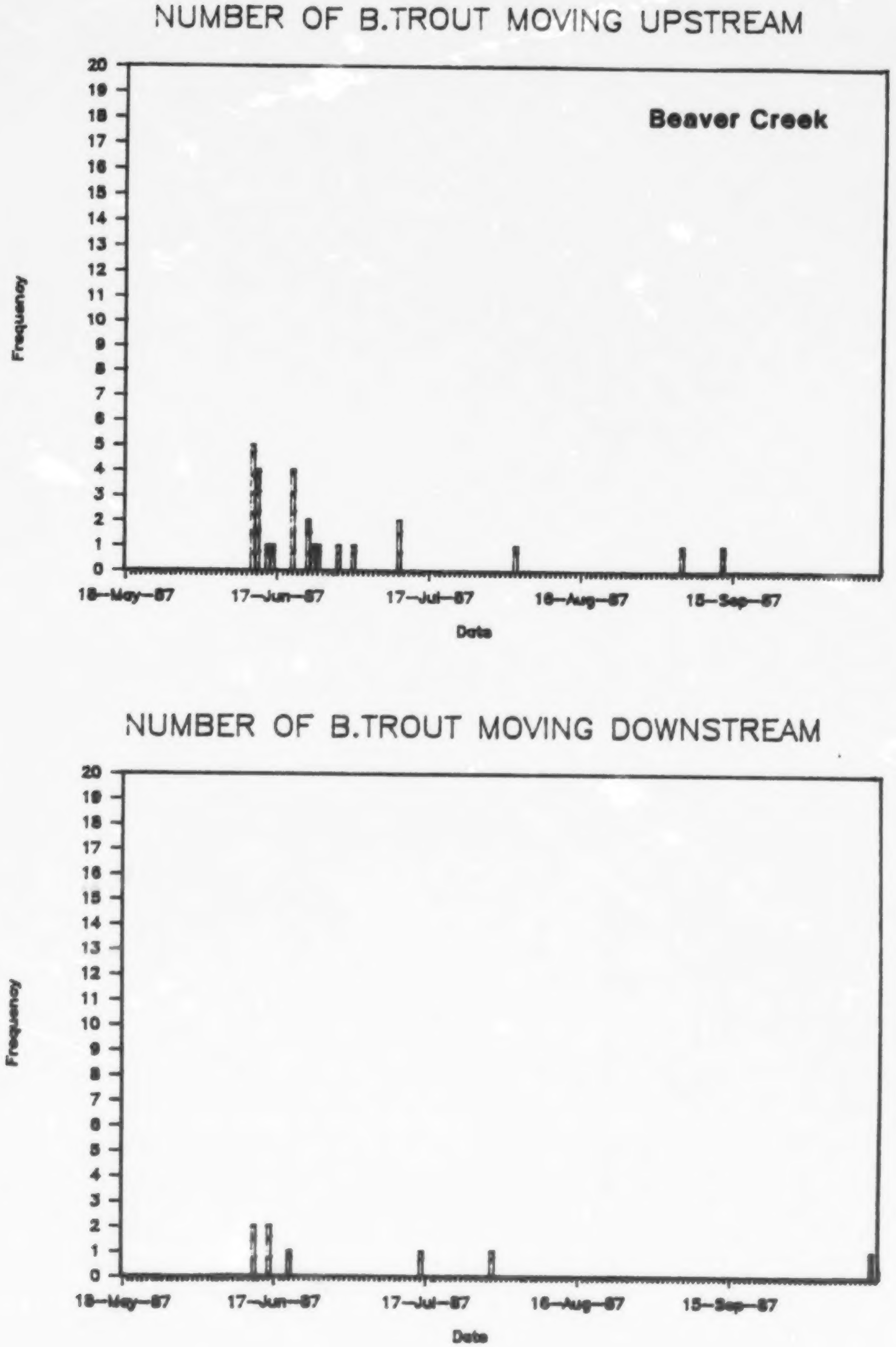


Figure 11: Frequency distributions for brook trout sampled moving upstream and downstream in Beaver Creek in 1987.

Table 3: Normalized Chi-square values for testing the equality of means and variances and their associated P-values for the variance to mean test on Moondance, CN1 and Beaver Creek fence frequency distributions.

Fence	Season	Trap Direction	Normalized Variable	P-Value	Frequency Distributions
Moondance	openwater	up	4.805	0.001	neg. binomial
		down	1.128	0.259	random
CN1	openwater	up	3.815	0.001	neg. binomial
		down	3.700	0.001	neg. binomial
Beaver	openwater	up	11.129	0.001	neg. binomial
		down	3.560	0.001	neg. binomial

movements into it for the entire openwater season was the Moondance Creek downstream fence (Figure 10). Problems were encountered with this trap however, as 10 of 18 brook trout tagged and recaptured in Moondance Creek in 1987 were sampled above or moving upstream past the fence on more than one occassion without having been sampled moving downstream. This indicates inefficient sampling by the Moondance fence downstream trap. This was not observed in any of the other traps.

Because brook trout capture frequency distributions contained predominantly zero's (i.e. the majority of days sampled no trout for any given fence) conventional variance stabilizing transformations did not homogenize the variances. Consequently, analysis of variance techniques to assess differences in the number of trout sampled in each trap were not possible. To circumvent this problem data were separated into approximately equally sized time periods and chi square tests of homogeneity of the distribution of zero and non-zero (i.e. capture frequencies of one to a maximum observed frequency of six were combined in one "non-zero" class) capture frequencies between season were done (Table 4). Time intervals of late May - July 6, July 7 - August 25, August 26 - October 14 are referred to as spring, summer and fall hereafter.

Significant differences in the distribution of zero and non-zero captures were noted for the Moondance Creek upstream trap. Trout were present in this trap on fewer days during summer than during the spring and fall (Table 4). The actual number of trout sampled in summer was also lower but the mean group size was slightly greater than in spring. The mean group size and total number of trout sampled was greatest in fall. This means that movements upstream on Moondance Creek

Table 4: Seasonal frequencies of days sampling no trout and days sampling ≥ 1 trout for openwater season fences in 1987 and associated chi square tests for homogeneity of seasonal effects. Average size of b. trout group sampled is presented in parentheses.

Creek	Trap Direction	Interval (Season)	Number of Days With Trout Sampled	Number of Days Without Trout Sampled	Overall Chi Square (P-Value)
Moondance	Upstream	May 17 - July 6 (Spring)	21 (1.3)	30	5.919
		July 7 - Aug. 25 (Summer)	10 (1.4)	40	(0.052)
		Aug. 26 - Oct. 14 (fall)	19 (1.9)	31	
	Downstream	May 17 - July 6	4 (1.3)	47	1.382
		July 7 - Aug. 25	4 (1.0)	46	(0.501)
		Aug. 26 - Oct. 14	7 (1.1)	43	
CN1	Upstream	May 20 - July 6	18 (1.7)	30	3.252
		July 7 - Aug. 25	11 (1.1)	39	(0.197)
		Aug. 26 - Oct. 14	18 (1.6)	32	
	Downstream	May 20 - July 6	14 (1.3)	34	5.861
		July 7 - Aug. 25	12 (1.3)	38	(0.053)
		Aug. 26 - Oct. 14	5 (1.6)	45	
Beaver	Upstream	May 19 - July 6	10 (2.1)	39	10.420
		July 7 - Aug. 25	2 (1.5)	48	(0.005)
		Aug. 26 - Oct. 14	2 (1.0)	48	
	Downstream	May 19 - July 6	3 (1.7)	46	1.091
		July 7 - Aug. 25	2 (1.0)	48	(0.580)
		Aug. 26 - Oct. 14	1 (1.0)	49	

were more "clumped" in the summer than in the spring and most clumped in the fall. No differences were observed in capture frequency distribution or mean group size sampled in the Moondance Creek downstream trap between seasons. Moreover the average group size was similar from season to season (Table 4).

CN Creek fence 1 data indicated a similar decrease in upstream moving trout (i.e. non-zero) in the summer; however the difference was not statistically significant (P=0.197). Moreover, the mean group size was smaller indicating a 50 percent decrease in the number of trout moving upstream in the summer. This means that clumping of upstream movement in the summer was not observed at CN1 fence. The difference in seasonal downstream zero and non-zero frequencies (P=0.053) indicates that fewer trout moved downstream in the fall at CN1 fence. While the mean group size was slightly larger for this period it does not indicate increased clumping on the same scale as observed for Moondance Creek upstream movement in the summer.

Beaver Creek upstream movements were largely confined to the spring (Table 4). The difference in zero and non-zero frequencies between seasons was significant (P=0.005). Moreover mean group size decreased as the sampling season progressed. While the same trend was noted for the downstream trap at Beaver Creek, the differences were statistically insignificant (P=0.580).

The size of individual trout moving past the fences in each of these creeks was different for any given creek, trap and season (Table 5). Weights of trout moving upstream on Moodance Creek correspond to juveniles and first time spawners in spring, summer and fall (230-260 grams). In the fall the average weight of 263.4 grams

Table 5: Moondance, CN1 and Beaver Creek fence brook trout capture information, 1987.

			UPSTREAM			DOWNSTREAM		
Creek	Interval	Number of Days	Number of B. Trout	Average Number (per day)	Average Weight (g) (per fish)	Average Number B. Trout	Average Number (per day)	Average Weight (g) (per fish)
Moondance	May 17 - July 6	51	27	0.53	260.2	5	0.10	130.0
	July 7 - Aug. 25	50	14	0.28	243.9	4	0.08	4.8
	Aug. 26 - Oct. 14	50	37	0.74	263.4	8	0.16	157.8
CN1	May 20 - July 6	48	30	0.63	51.9	18	0.38	20.8
	July 7 - Aug. 25	50	12	0.24	13.7	15	0.30	17.1
	Aug. 26 - Oct. 14	50	28	0.56	94.1	8	0.16	32.5
Beaver	May 19 - July 6	49	21	0.43	1.2	5	0.10	1.4
	July 7 - Aug. 25	50	3	0.06	3.7	2	0.04	5.5
	Aug. 26 - Oct. 14	50	2	0.04	343.0*	1	0.02	25.0

* (6.0 + 680.0) / 2 = 343.0 g.

was composed of primarily small mature males and a few larger mature females. Downstream moving trout sampled were on the average 0^+ - 1^+ year old.

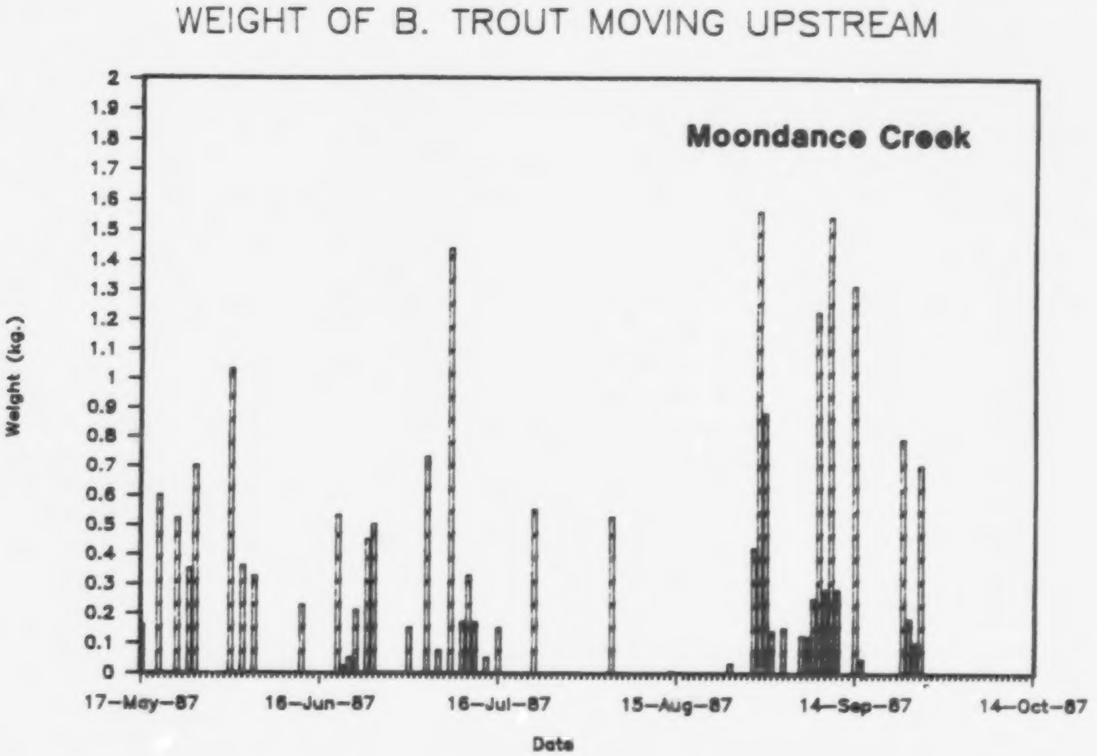
CN1 fence trout tended to be small with average weights corresponding to 0^+ and 1^+ year old brook trout (Table 5). There was a tendency for y.o.y. brook trout to be sampled moving upstream in summer hence the 13.7 g average weight in the summer. Some evidence for increased upstream movements of yearling trout in spring and fall in CN Creek is represented by higher average weights during these times. Downstream moving trout tended to be yearlings in spring and 0^+ - 1^+ year old in summer and fall.

With the exception of one 680 g brook trout sampled in the fall, all trout captured in the Beaver Creek fence were 0^+ years old (Table 5). Sizes ranged from 1 g to 25 g over the openwater season.

The total weight of brook trout sampled daily at each fence is presented in Figures 12-14. Clearly movements into Moondance Creek represent the most significant biomass of brook trout of the three tributaries studied.

The number of brook trout moving into and out of CN Creek are given by the July 23-September 22 CN2 fence data (Figure 15). The low weight of trout moving upstream and downstream indicates that those trout sampled were almost entirely y.o.y. brook trout (Figure 16). No evidence of a spawning run into CN Creek can be inferred from this data with the exception of one 390 g upstream migrant on August 28, 1987.

Additional information regarding brook trout movements was supplied through marked trout recaptures on CN and Moondance Creeks. It



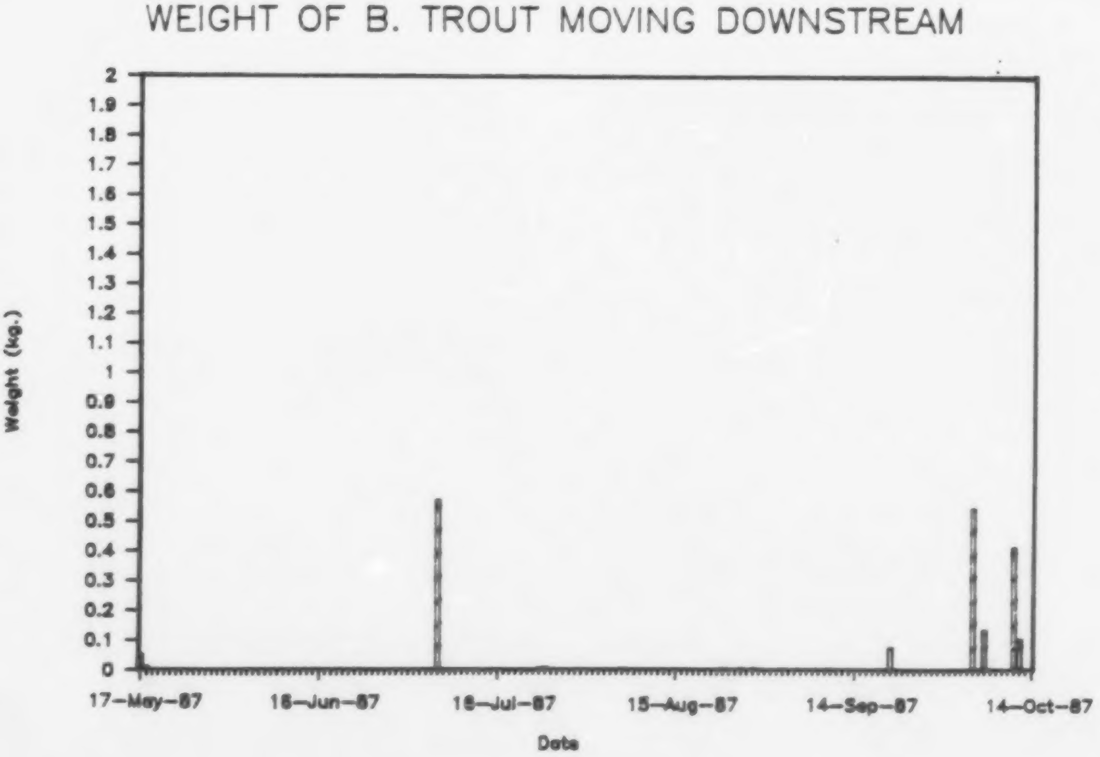
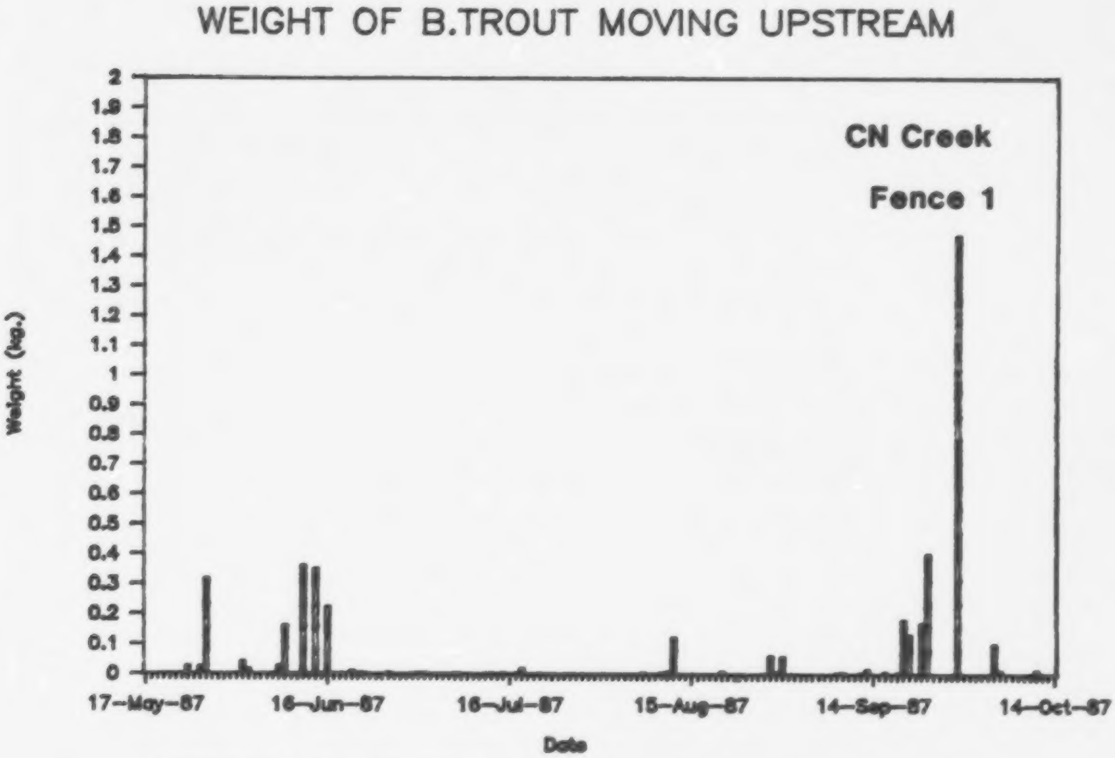


Figure 12: Total daily weight distributions for brook trout moving upstream and downstream in Moondance Creek in 1987.



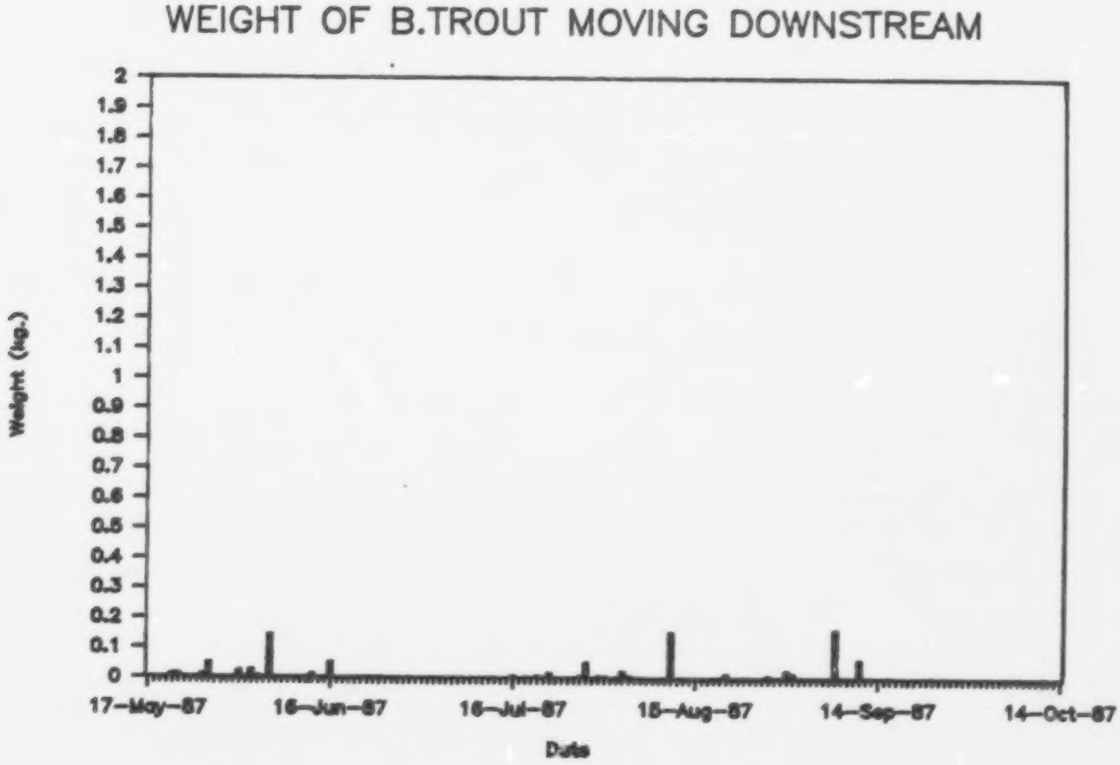
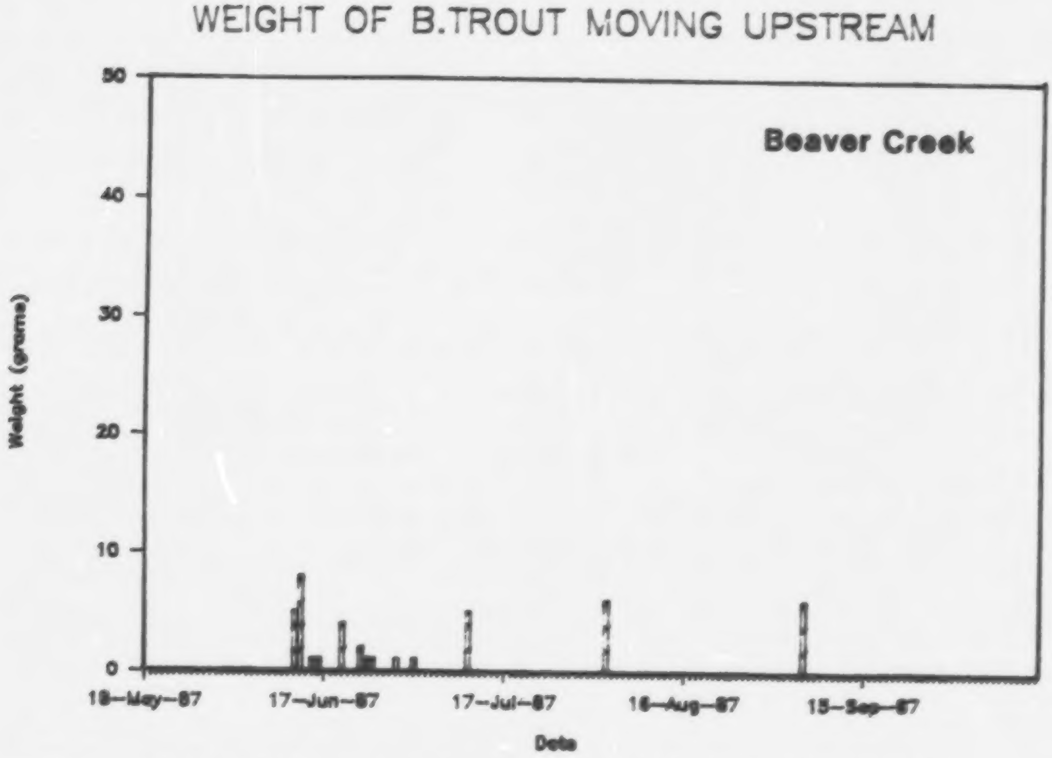


Figure 13: Total daily weight distributions for brook trout moving upstream and downstream in Moondance Creek in 1987.



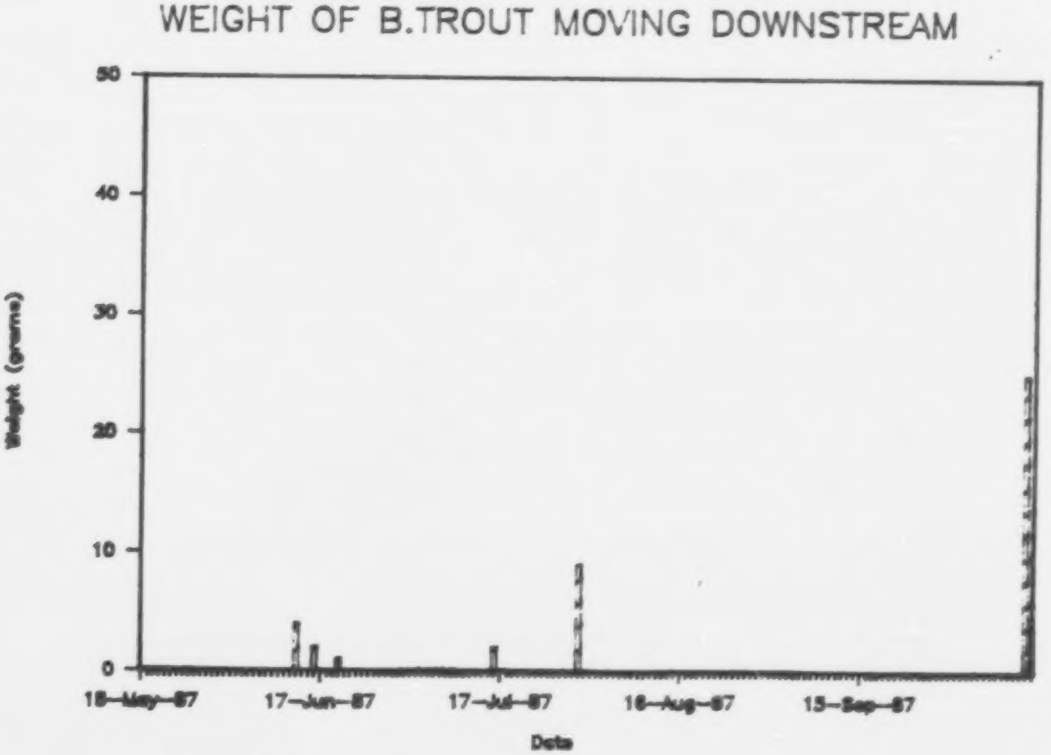


Figure 14: Total daily weight distributions for brook trout moving upstream and downstream in Beaver Creek in 1987.

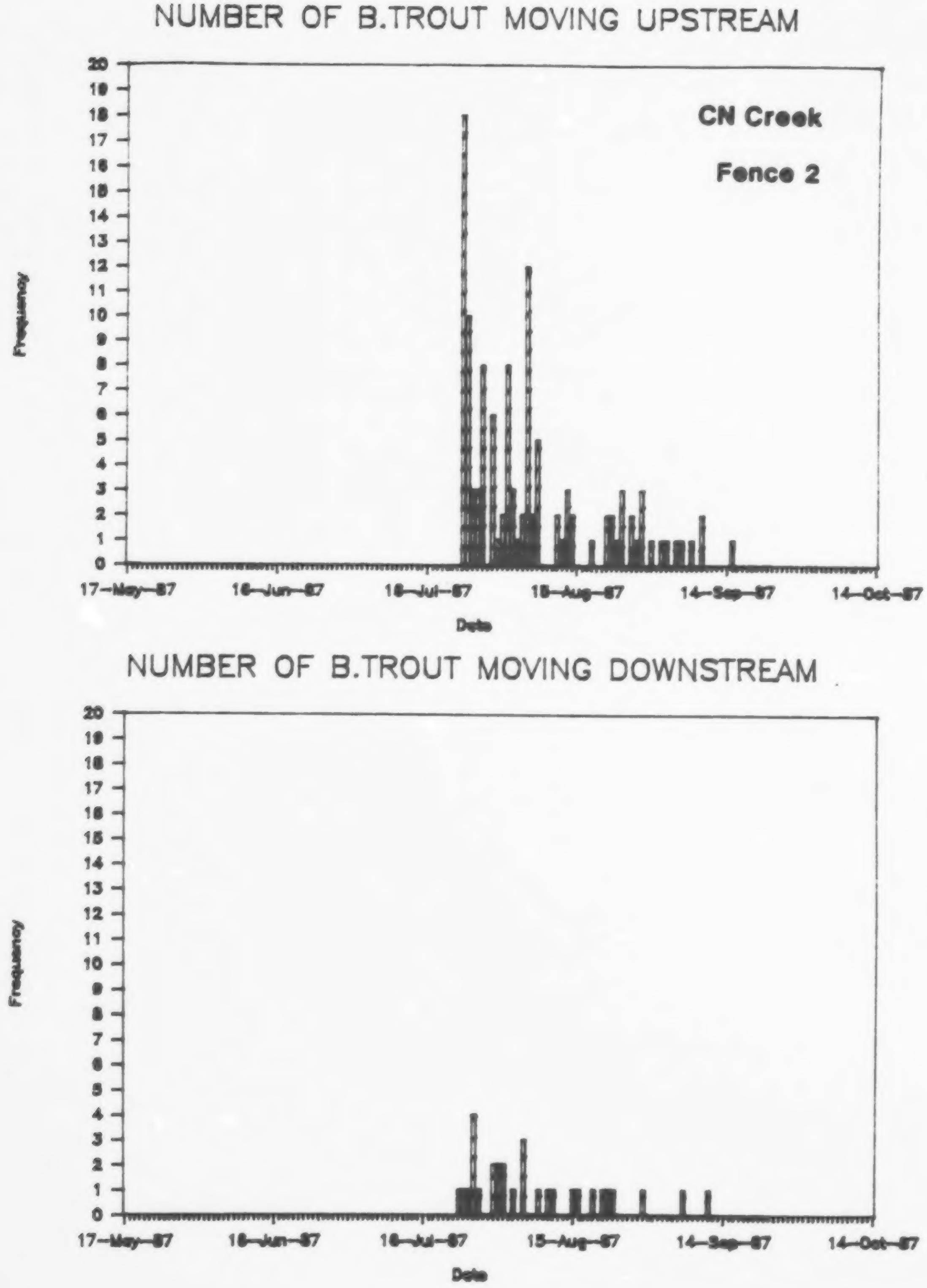
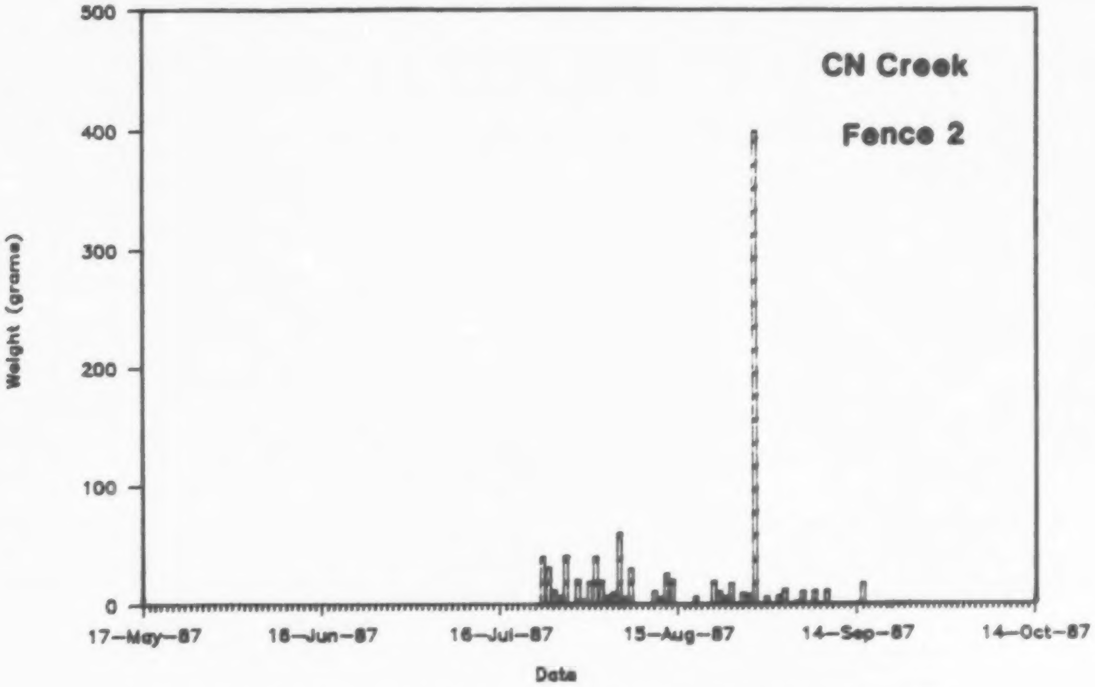


Figure 15: Frequency distributions for brook trout moving into and out of CN Creek from July 23 to September 22, 1987.

WEIGHT OF B.TROUT MOVING UPSTREAM



WEIGHT OF B.TROUT MOVING DOWNSTREAM

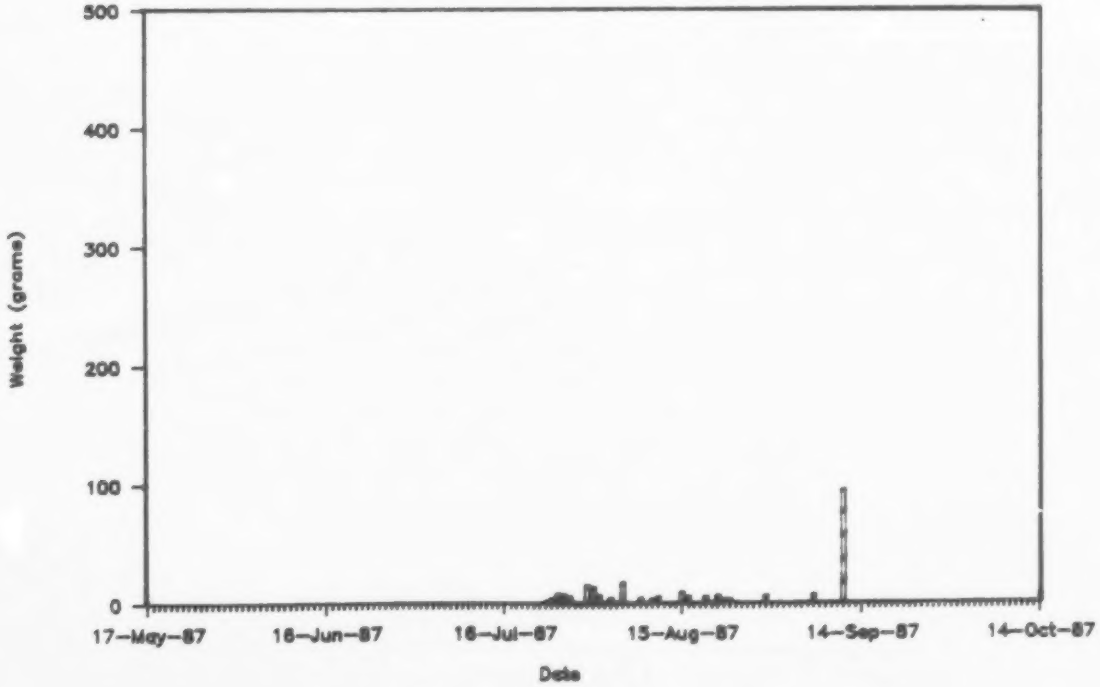


Figure 16: Total daily weight distributions for brook trout moving into and out of CN Creek from July 23 to September 22, 1987.

was observed that three y.o.y. brook moved upstream past CN2 and CN1 fences in summer and two larger brook trout (100 g and 375 g) were Floy tagged 1 km upstream of CN1 fence and were subsequently recaptured during moving downstream at CN1 fence in early September.

Brook Trout Utilization

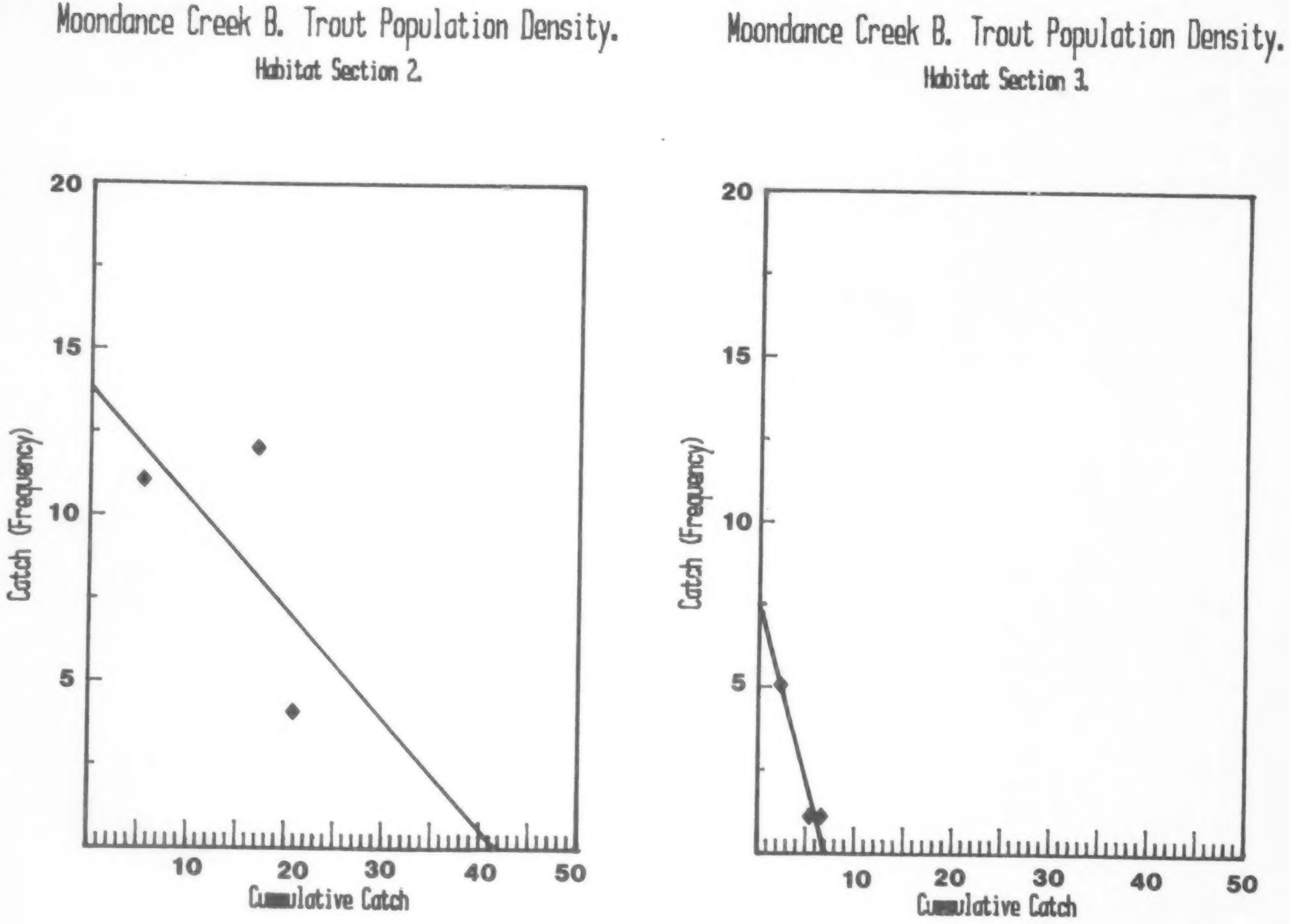
Brook trout capture information for the ten 100 m sections surveyed are presented in Table 6. CN Creek section 1 was not electroshocked however, because the water was stagnant and as a result a buildup of algae and natural siltation reduced visibility when electroshockers attempted to sample it. The highest utilization per unit area and effort was in the CN Creek section 3 while the largest absolute numbers of brook trout sampled were in Moondance Creek sections 2 and 3. In fact removal estimates of the number of 0^+ brook trout were only calculated for Moondance Creek section 2 and 3 (Figure 17). The estimated values are 41 and 7 respectively. Section 2 is located just upstream of a large beaver dam and section 3 just below the same beaver dam.

Data collected in Beaver Creek revealed that brook trout up to 2^+ years old were present (Table 6). This despite only 0^+ year old brook trout being sampled in the Beaver Creek fence.

As a consequence of field observations a mark-recapture experiment was carried out between the two CN Creek fences in early fall (Table 7). As indicated, in the order of 650 y.o.y. and yearling brook trout resided in this 400 m section of CN Creek. An approximate ratio of young of the year to yearling trout was calculated from length

Table 6: Brook trout capture information for 100 m sections electroshocked on Moondance, CN and Beaver Creeks, 1987.

Creek	Section Number	Date Sampled	Mean Channel Width (m)	Section Length (m)	Seconds Shocked	B. Trout Frequency (no./m /100 sec)	B. Trout Density (g./m /100 sec)
Moondance	1	21/08/87	6.9	100	500	0.001 (3)	0.006 (20)
	2	20/08/87	5.4	100	2199	0.002 (29)	0.017 (196)
	3	15/08/87	5.2	100	389	0.004 (10)	0.097 (196)
	4	14/08/87	6.6	100	450	0.002 (5)	0.012 (35)
CN1	1	----	2.2	100	0	----	----
	2	26/08/87	2.2	100	1084	0.001 (3)	0.020 (47)
	3	25/08/87	1.9	100	653	0.005 (6)	0.193 (239)
Beaver	1	22/08/87	4.4	100	970	0.000 (0)	0.000 (0)
	2	23/08/87	3.2	100	759	<0.001 (1)	0.002 (6)
	3	04/09/87	3.2	100	804	0.002 (4)	0.068 (178)



Moondance Creek B. Trout Population Density. Habitat Section 2.

Moondance Creek B. Trout Population Density. Habitat Section 3.

Figure 17: Regression estimates of brook trout abundance for Moondance Creek habitat sections 2 and 3 in August 1987.

Table 7: Mark - recapture estimates and 95% confidence intervals for one 400 m long section of CN Creek in 1987.

Samples	Marks (M)	Total Captures (C)	Recaptures (R)	Population Estimate (N)	Confidence Interval (95%)
Modified Petersen (29/08/87)	91	72	9	671	367-1328
Modified Petersen (02/09/87)	91	93	13	617.7	371-1094
Modified Schnabel (combined dates)	91	165	22	652.8	424-962

+ Confidence Intervals were obtained by assumming that Recaptures (R) were Poisson in nature and using Ricker's (1975) confidence limits for poisson variables.

intervals. The ratio was approximately 14:1 indicating that roughly 50 yearlings and 600 y.o.y. brook trout inhabited that section of the stream. This section of the stream corresponds closely to the shaded area in Figure 6 representing 82% of the groundwater sites.

DISCUSSION

All three tributaries studied can be labelled "nursery tributaries". Immature brook trout (0^+ - 2^+ years old) were sampled in all three tributaries throughout the season and relatively few mature adults were sampled ($\geq 3^+$ years old). Certainly, no trophy brook trout were sampled in any of these three creeks. This supports past studies which indicated that these small tributaries serve as a nursery habitat (Gaboury 1980; Gaboury and Spence 1981; Swanson 1986; Swanson and Kansas 1987). In fact, the densities at which immature brook trout were noted in CN and Moondance creeks indicates their importance with respect to stock recruitment in the Nelson River.

Movements into tributaries were probably the result of different factors for each creek studied. Migration into Moondance Creek was closely associated with discharge rates (Figure 4). As can be interpreted from Figures 4 and 10, 11 of the 14 brook trout sampled moving upstream in the summer on Moondance Creek, i.e. 79%, were sampled during small summer spates. Similarly the movement of 47% of the openwater season's total was during the fall spate (i.e. the spawning run). The reason for this association probably lies in the fact that if the water is not of sufficient depth for fish passage, migrations will not occur. To some extent discharge was related to the movement of groups of trout into all three of the study streams. Discharge rates have been correlated to brook trout migrations previously, describing upstream spring-summer nursery movements (Gaboury 1978; 1980) downstream emigrations due to lack of available habitat at low flows (O'Connor

1974) and fall upstream spawning runs (Gaboury 1978). The inefficiency of the downstream trap on Moondance Creek cannot be overlooked, and it is possible that a number of the upstream migrants were in fact just resident trout which were not sampled moving downstream. This theory is supported by the fact that large numbers of northern pike are present at the mouth of Moondance Creek. Their presence there would reduce the chances of juvenile brook successfully navigating into Moondance Creek from the Nelson River.

In CN Creek, upstream movements into CN Creek were most likely a consequence of low water temperature. As noted for CN2 fence data (Figure 15) all but two of the trout moving upstream during July 23 - September 22 were young of the year. Latta (1969) found cold water temperatures were selected by and critical for the survival of y.o.y. brook trout. Temperatures in CN Creek were in the order of 10-12°C lower in CN Creek than in the Limestone River proper. It is of interest to note that upstream migrants in Moondance Creek were generally in the 2^+ years old size range and temperatures in Moondance Creek averaged 10°C higher than they were in CN Creek through July and August (Figures 3 and 4). Moreover, no summer or fall spates could be correlated to upstream movements on CN Creek (Figures 3 and 15). Movements at CN1 fence are believed to be simply dispersal in nature.

Upstream migration in Beaver Creek was a result of the opportunity Beaver Creek afforded brook trout y.o.y. in the Nelson River. As noted previously brook trout fry are subject to drift during peak spring flows (Swanson and Kansas 1987). Consequently trout fry of Limestone River origin are undoubtedly swept into the Nelson River.

These fry subsequently immigrate into available stream habitat along the north shore as was observed at Beaver Creek in 1987 (Figure 5). The reasons for emigration from the Nelson River into small tributaries may be simple. The Nelson River is very turbid and those items visible to visual surface feeders, i.e. brook trout alevins and young juveniles (Williams 1981) could be too large to be successfully consumed (Raleigh 1982). Because young trout tend to concentrate in areas of reduced current velocity, i.e. sheltered bays and creek mouths, and because the clear tributary water affords better feeding opportunities, brook trout y.o.y. immigrate into Beaver Creek. Moreover, the fact that trout fry are only susceptible to currents for a short period in the spring aids in explaining the seasonal "clumping" of trout movements, i.e. fry moved upstream in Beaver Creek in the spring. It is also possible that rapidly varying flows in the Nelson River reduces the hospitability of the Nelson River environment. Small tributaries may therefore offer a more constant and hospitable environment for y.o.y. brook trout.

Implicit in the explanation for Beaver Creek's and CN Creek's upstream moving y.o.y. brook trout is the presence of an upstream "source" of y.o.y. trout. Clearly the Limestone River is the source for upstream migrants in Beaver and CN Creeks. Conversely, the closest possible source for Moondance Creek is Brooks Creek which is 8-9 miles upstream. Moreover, the constriction of flow at the Upper Limestone Rapids probably results in any y.o.y. trout being swept downstream past Moondance Creek which is at the bottom of the major rapids shelves (Figures 1 and 2). This probably explains the lack of upstream migrant y.o.y. brook trout at Moondance Creek.

Downstream movements were not observed in any near semblance of upsteam movements. The only occassion where this might be blamed on sampling inefficiences is believed to be at Moondance Creek. No other evidence for "one way" sampling was noted and relatively low flows on CN and Beaver Creek made fence maintenance easier and as a consequence more thorough. It therefore seems that brook trout moved out of these streams either in the spring prior to fence installations or in the fall after fence removal.

Overwintering of juvenile brook trout in CN and Moondance Creeks is probable. Conditions in the winters of 1986-87 and 1987-88 afforded overwintering habitat as groundwater areas and springs provided year round flow. In fact brook trout were observed in early March of 1988 in CN Creek. Overwintering in Beaver Creek however, remains questionable. Mild winter conditions in 1986-87 may have provided year round flow as was observed for the similarly sized stream Tiny Creek. More severe winter conditions and the presence of a temporary crossing upstream, froze Tiny Creek solid in the winter of 1987-88. This maybe indicative of similar conditions affecting Beaver Creek in the winter of 1987-88.

Brook trout utilization extends itself to spawning in CN and Moondance Creeks. Evidence of this includes: the presence of drifting brook trout eletheurembryos and alevins in both CN and Moondance Creeks; y.o.y. brook sampled above a 2 m beaver dam which has been present since 1985 on Moondance Creek; an upstream run of small ripe male trout and larger mature females in the fall in Moondance Creek; and the observations of redd building and spawning behaviour in CN Creek.

The reasons for spawning relate to the presence of groundwater in CN and Moondance Creeks. Groundwater upwellings were detected near and at the spawning area on CN Creek and the relatively cold water temperature emphasizes the strength of the groundwater influence there. Moreover, springs are active year round on Moondance Creek where spawning is believed to occur. Numerous authors have documented the preference of brook trout to spawn in areas of groundwater upwellings (Webster and Eiriksdottir 1976; Carline and Brynildson 1977; Carline 1980; Witzel and MacCrimmon 1983).

Beaver Creek does not harbor a spawning brook trout population. The fact that the drift traps sampled a majority of the flow and yet failed to sample one brook trout fry is testimony to their absence in Beaver Creek drift. Moreover, the presence of y.o.y. brook trout can be explained by immigrating trout fry swept out of the Limestone River at peak spring discharges. Finally no run of mature trout was noted in Beaver Creek during the spawning period. It is believed that groundwater, cover and discharge are insufficient to support spawning adults in Beaver Creek. Another possible explanation lies in the theory that mature trout in the Nelson River are attracted by odors of the Limestone River plume to the exclusion of small north shore tributaries. Other authors have determined that very small levels of attractants are required to stimulate a response in arctic char (Salvelinus alpinus) (Doving et al. 1973; Selset and Doving 1980; Doving et al. 1980) the salmonid most closely related to brook trout. In fact, their theory as to which chemical stimulates homing responses in arctic charr, points to by-products of successful spawning and rearing of y.o.y. charr as the odoriferous cue. Consequently, the relative plethora of y.o.y. brook trout by-products dispering into the Nelsn River from the Limestone River may mask those less distinct odor plumes associated with smaller tributaries.

The level of utilization of these streams appears to relate to stream discharge and the relative strength of groundwater. Utilization levels were highest (per unit area) in CN Creek which also exhibited the strongest groundwater presence as reflected in low temperatures season long. Second highest utilization levels were found in Moondance Creek which as the largest creek (drainage area = 45 km^2) had the greatest holding volume. Moreover, utilization levels in both creeks was greatest in areas of groundwater recharge. While Beaver Creek's groundwater contribution is at present unknown it may be presumed that due to its small size and steep gradient it had the least volume of trout holding capacity and transversed the water table over the shortest distance. This may have functioned to limit the presence of gravity type groundwater recharge to fewer sites than in CN and Moondance Creek. By corollary a lower level of utilization by juvenile brook trout follows. It is believed that for the most part groundwater recharge is of the gravity type described by Rutilis (1985) (see Part 3).

Groundwater may function to limit y.o.y. trout densities through effects on territoriality. While y.o.y. trout were observed to school in CN Creek at 5-6°C, they maintained discrete territories (under rocks, along edges in cover etc). in Moondance Creek at 12-15°C. This is supported by Cunjak and Power (1986) who found that immature brook trout school in the winter in pools and by Gibson (1978) who found that at 9°C

40% of the brook trout present exhibited winter hiding behaviour. This phenomemon would then explain the schools of trout y.o.y. and higher densities in CN Creek and the dispersed, lower density distribution of y.o.y. brook trout in Moondance Creek. The disbenefits of cold groundwater may manifest themselves in lower growth rates (Fry 1971).

CONCLUSIONS

1. Limestone River tributaries, north shore tributaries in the Conawapa Forebay area and Moondance Creek are nursery tributaries.
2. Spawning occurs in CN and Moondance Creeks.
3. Immature brook trout in Beaver Creek (and by extrapolation) other north shore tributaries) are immigrants; young of the year trout from upstream source streams, and juvenile brook trout from the Nelson River.
4. Groundwater and stream size determine the type (spawning and rearing) and level of utilization, i.e. the larger the stream and the stronger the groundwater influence the greater the use by immature brook trout.

RECOMMENDATIONS

1. Angling should be prohibited in brook trout "nursery streams" where large brook trout are seldom present.

2. Stream crossings in the Conawapa Forebay area should maintain stream habitat integrity through:
    1) adequate erosion control,
    2) minimum stream disruption during installation,
    3) as expedient an installation as possible,
    4) winter installations where feasible, for Moondance, Sundance, Beaver, Swift, Tiny, Goose, 15, 18, Anyways and 23 Creeks.

3. Stream crossings in the Conawapa Forebay area should maintain access to upstream nursery habitat for immature brook trout through the maintenance of adequate flow requirements (i.e. depth and velocity) for passage of immature brook trout during the late spring-late summer interval in Moondance, Sundance, Beaver, Swift, Tiny, Goose, 15, 18, Anyways and 23 Creeks.

4. Aggregate borrow and exploration activities should ensure that sufficient buffer strips are maintained to prohibit erosion and protect stream habitat.

5. Measures must be taken to ensure that fuel is not spilled in aggregate borrow/exploration areas.

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GROUNDWATER

INTRODUCTION

The amount of groundwater flow in streams is an important factor in determining stream ecology. Winter baseflows are determined by the amount of groundwater, as precipitation is stored as snow on the land and runoff is minimal (Newbury 1984). As such, groundwater determines the amount of winter habitat available for overwintering stream organisms.

Groundwater is of particular importance with regards to brook trout (Salvelinus fontinalis). Brook trout commonly spawn in areas of groundwater upwelling (Carline and Brynildson 1977; Carline 1980; Witzel and MacCrimmon 1983) and will select groundwater upwelling sites over similar sites with no upwelling for spawning (Webster and Eiriksdottir 1976). Groundwater is also important in determining the survival of underyearling brook trout (Latta 1969) and in providing suitable overwintering habitat (Raleigh 1982). Groundwater may be of even greater importance to brook trout in the Nelson River watershed which is near the northern limit of brook trout distribution. Severe winter conditions may mean that groundwater determines the amount of overwintering habitat for all stages of brook trout life history.

Because groundwater may be critical to brook trout stocks in the lower Nelson River, identification of groundwater upwellings will aid in the location of sensitive brook trout habitat. This information will then be applied to work permit conditions (re: proposed M. Hydro activities) to mitigate damages to stream ecosystems in the lower

Nelson River watershed. Information garnered will also provide biological information with respect to brook trout stock survival strategies in the lower Nelson River and may detect sites suitable for instream enhancement activities.

For the above reasons aerial surveys of several streams in the lower Nelson River watershed were undertaken in late August, 1987 to identify groundwater intrusion sites. Surveys were done using the Federal Department of Fisheries and Ocean's (DFO) Forward Looking Intra Red (FLIR) thermal sensing device.

METHODS

Groundtruthing

Two creeks (Wilson and CN Creeks), were groundtruthed for the presence of coldwater upwellings (i.e. groundwater). Truthing was done by measuring water temperatures below the stream bed during late July, 1987 to maximize the difference between ambient stream temperature and groundwater temperature. Temperature measurements were taken every 20m (± 5m) over the stream "test reach" using a Fluke model 51 electronic thermometer and a 24 inch K-type thermocouple encased in stainless steel.

Those sites which indicated subsurface temperatures of 6°C or less were identified by placing a large numbered flag face up on shore beside the site. These sites were later identified during FLIR surveys and when possible on FLIR imagery.

FLIR Surveys

The FLIR device was mounted on a Bell 206 Jet Ranger (Custom Helicopters Ltd., Thompson, Man.) and was operated by Electromagnetic Sensing and Interpretation (E.M.S.I.) of Winnipeg, Man. Preliminary surveys were flown at dawn, solar noon and dusk to determine the optimal thermal conditions for contrasting water surface thermal variations (i.e. locating cold water plumes). Subsequently FLIR surveys were flown before sunrise daily, to minimize thermal variability introduced by solar heating. Surveys were flown at an elevation of about 20m above the stream and at air speeds of 10-20 mph (conditions permitting).

FLIR imagery was output to video cassette (VHS format). Navigational information was recorded on enlarged National Topographic Surveys (NTS) 1:50,000 maps and on the audio channel of the video cassette recorder. The FLIR monitor, control box and VCR were mounted in the front of the helicopter to maintain visual reference with the survey stream by the operator.

Streams were surveyed in three different geographic areas: 1) Limestone Forebay tributaries, 2) Limestone River tributaries and 3) remote downstream tributaries. In total eleven streams were video taped using FLIR in an attempt to determine the distribution of groundwater and its relative contributions to stream habitat.

RESULTS

Groundtruthing

Canopy cover was too dense on CN Creek to maintain satisfactory coverage of the stream with the FLIR. CN Creek was however sampled by hand for the distribution of groundwater. In total eleven sites were identified (Table 1). All but sites number 1 and 2 were located in the first 600m of CN Creek. Sites 1 and 2 were located approximately 3 km upstream from the mouth of CN Creek. As can be noted from Table 1 the presence of groundwater was at times reflected in a noticeably lower water surface temperature (eg. site 1) and at times it was not as noticeable (eg. site 4).

Actual assessment of FLIR's abilities was done on Wilson Creek intrasubstrate temperature data. Of the 33 sites identified as groundwater upwellings 26 sites could be positively located on the FLIR videotape. Only seven of these sites exhibited coldwater plumes at the original ground truth site, i.e. 27% success (Table 2). In fact FLIR imagery failed to detect three of four cold water springs entering Wilson Creek (sites 7, 11 and 19). FLIR did however identify coldwater upwellings within a maximum of 20m downstream from each of these sites. It appears that stream hydraulics and groundwater discharge volumes play a role in the manifestation of coldwater upwellings. In some cases coldwater was not detected by FLIR for some distance downstream of an intrusion site.

On a larger scale FLIR analyses showed peak numbers of groundwater upwellings in a similar distribution pattern on Wilson Creek

Table 1: **Ambient stream temperatures and site specific water temperatures at identified groundwater sites on CN Creek 1987 (from Part).**

Date	Groundwater Site	Ambient Stream Temperature (°C)	Surface Temperature (°C)	Intrasubstrate Temperature (°C)
07/21/87	1	11.0	5.1	4.3
	2	11.0	8.8	4.8
	3	13.0	4.9	4.8
	4	13.0	12.3	5.2
	5	13.0	5.3	5.3
	6	13.0	12.1	4.0
07/22/87	7	11.0	9.2	5.2
	8	9.0	7.8	4.5
	9	7.6	5.6	4.4
	10	7.6	7.6	3.8
	11	7.7	7.6	4.6

Table 2: Groundtruthing water temperature and correlation of sites with FLIR for Wilson Creek data, 1987

Date	Groundwater Site	Ambient Stream Temperature (°C)	Intra Substrate Temperature (°C)	FLIR Correlation
July 22-26	1	13.4	5.3	Yes
	2	16.3	4.2	No
	3	16.4	2.5	No
	4	15.3	6.8	No
	5	14.8	6.0	No
	6	14.9	4.0	No
	7	15.2	3.8*	No
	8	14.2	6.4	No
	9	15.2	6.9	No
	10	15.2	4.8	Yes
	11	16.0	1.6*	No
	12	17.6	4.4	Yes
	13	16.9	6.2*	Yes
	14	12.8	6.6	No
	15	15.6	6.2	No
	16	18.2	6.9	No
	17	13.5	6.9	No
	18	18.0	6.6	No
	19	17.9	3.6*	No
	20	18.7	5.0	No
	21	18.6	6.0	Yes
	22	18.5	5.2	No
	23	17.7	6.6	No
	24	17.0	4.6	Yes
	25	18.9	6.3	No
	26	18.6	5.4	Yes

*Coldwater spring entering Wilson Creek.

to groundtruthing data (Figure 1). Other than identifying more sites for the first 3-4 km (tape counts 200-218) the distribution of upwellings was similar.

FLIR Surveys

FLIR imagery from the eleven tributaries surveyed was assessed for each contour interval as indicated on 1:50,000 NTS maps. Data are summarized in Appendix 3. As can be seen in Figure 2, as overall stream elevation (indicated by Creek Mouth elevation - in meters above sea level) decreased so did the mean contour elevation (determined by dividing the sum of the boundary contours by two) with the highest frequency of coldwater upwellings (no. per km). In fact for Nelson River tributaries the contour interval with the highest frequency of upwellings decreased from 84-90m on Sky Pilot and Wilson Creeks to 69-76m on Moondance Creek to 60-70m on Swift and Anyways Creeks (Figures 3-8). Goose Creek values peaked in the 70-80m contour interval, however three of the four identified sites in that interval were closed to the 70m contour, perhaps indicating a similarity to Swift and Anyways Creeks.

Gradient did not appear to be related to peak frequency of coldwater upwellings. A plot of frequency values and gradient for each contour interval was of no value. Regression statistics revealed no significant relationship between gradient and frequency of groundwater upwellings.

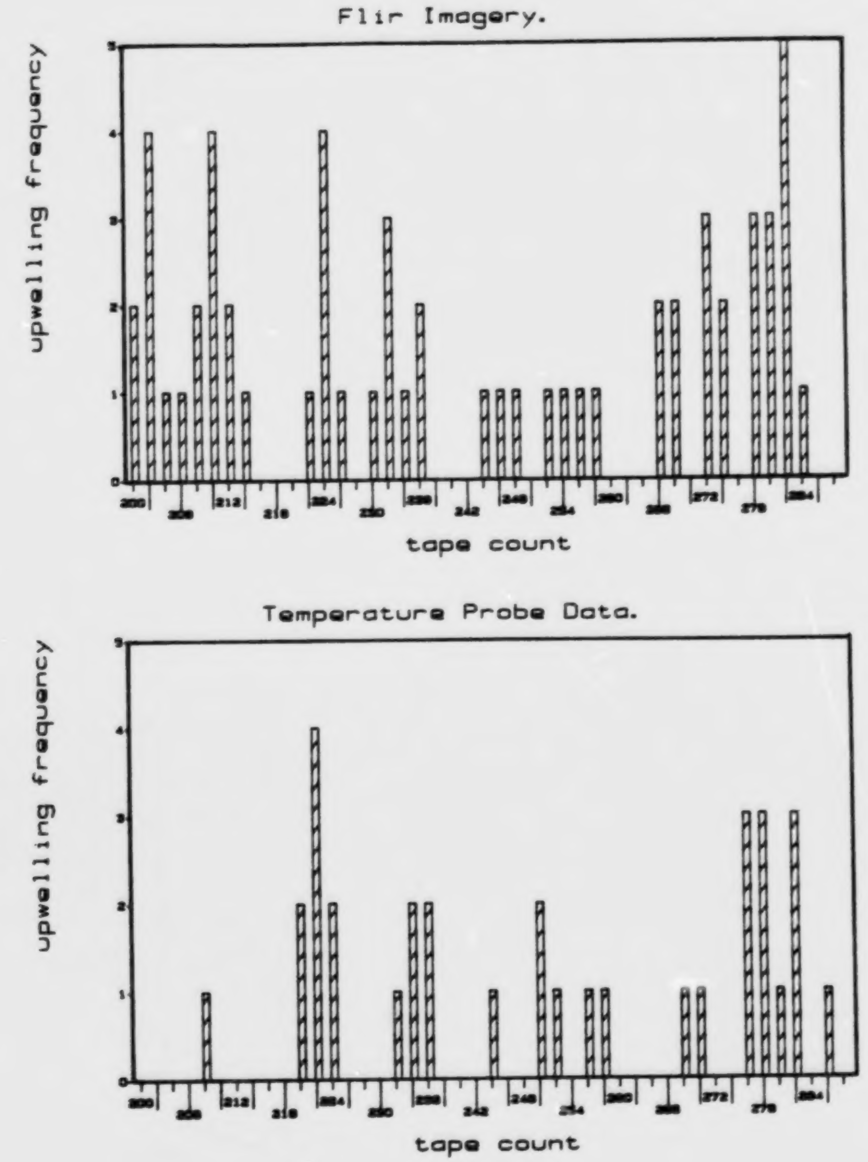


Figure 1: Comparison of groundwater upwellings as indicated by FLIR imagery and by groundtruth data for Wilson Creek, 1987. (Tape count is a measure of distance).

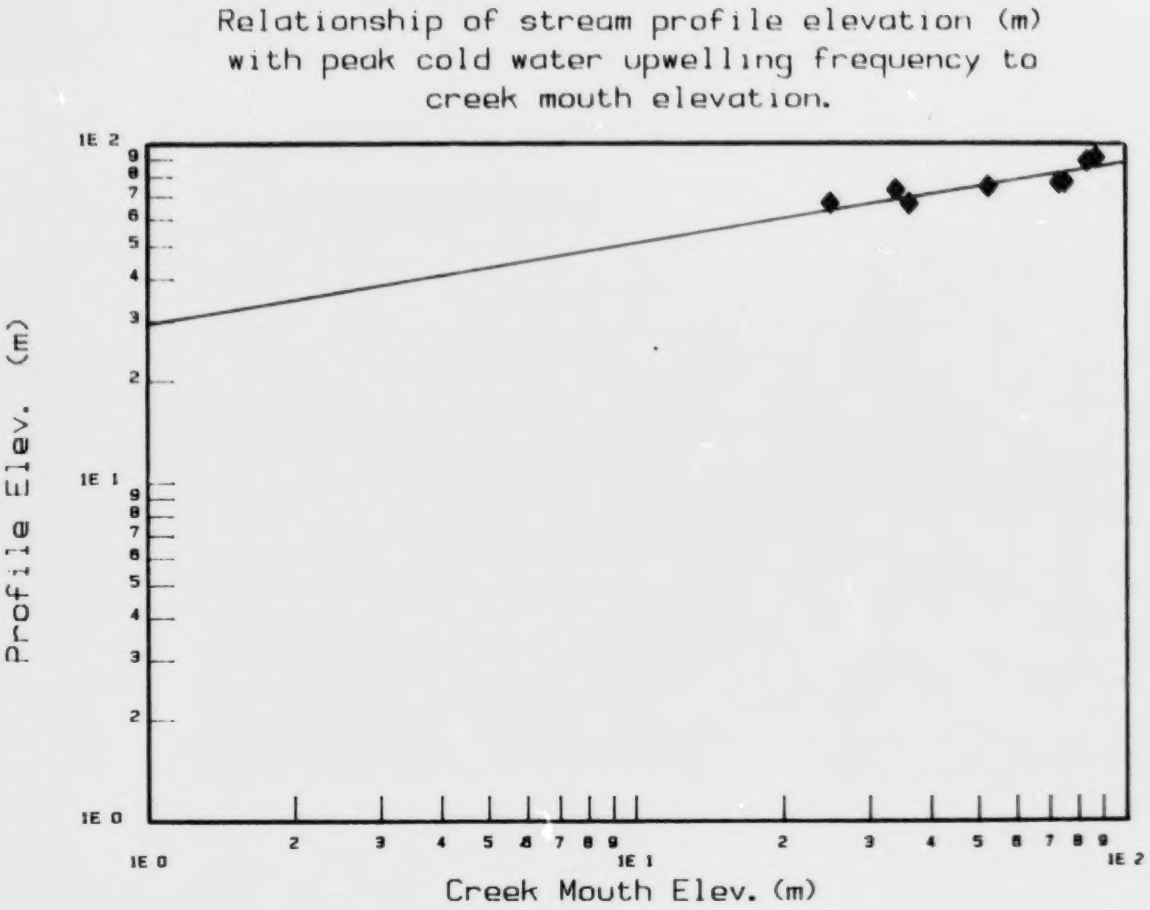
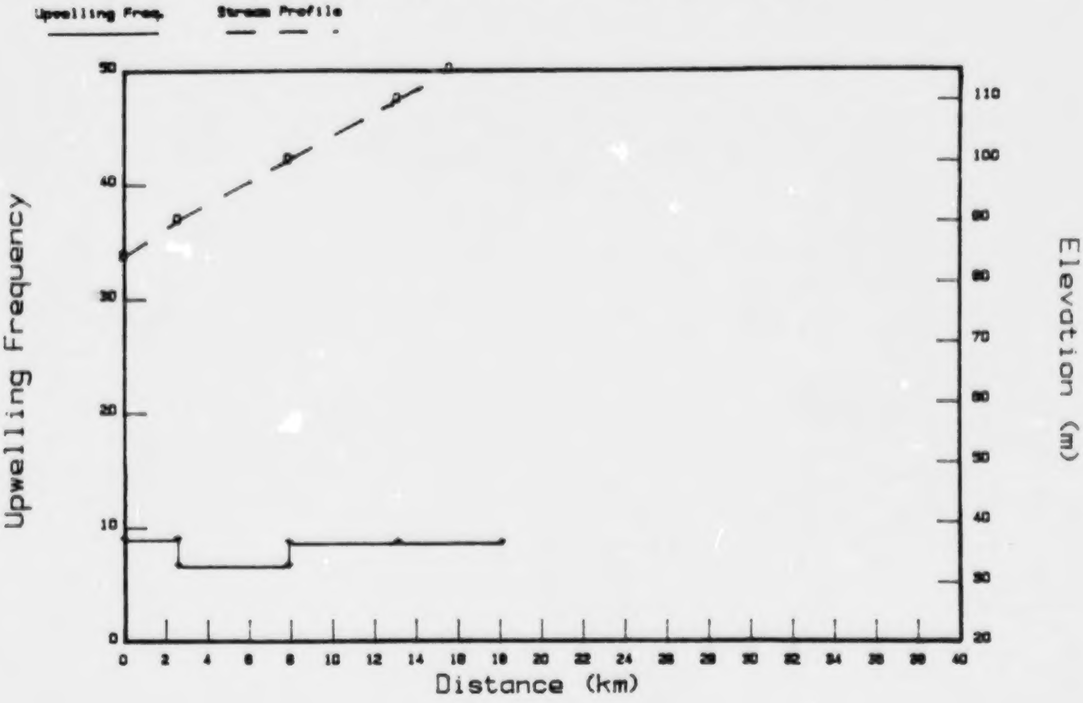


Figure 2: Relationship of stream profile elevation (m) with peak cold water upwelling frequency to creek mouth elevation.

Frequency of cold water upwellings (no. per km)
and stream profile for Wilson Creek.



Frequency of cold water upwellings (no. per km)
and stream profile for Sky Pilot Creek.

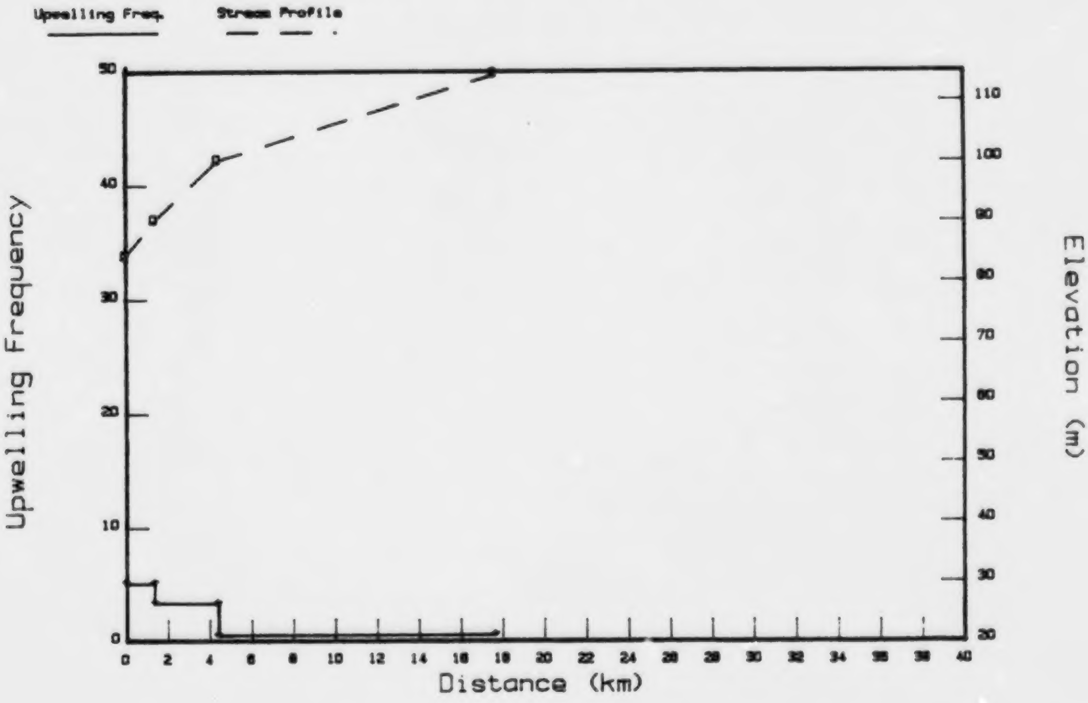
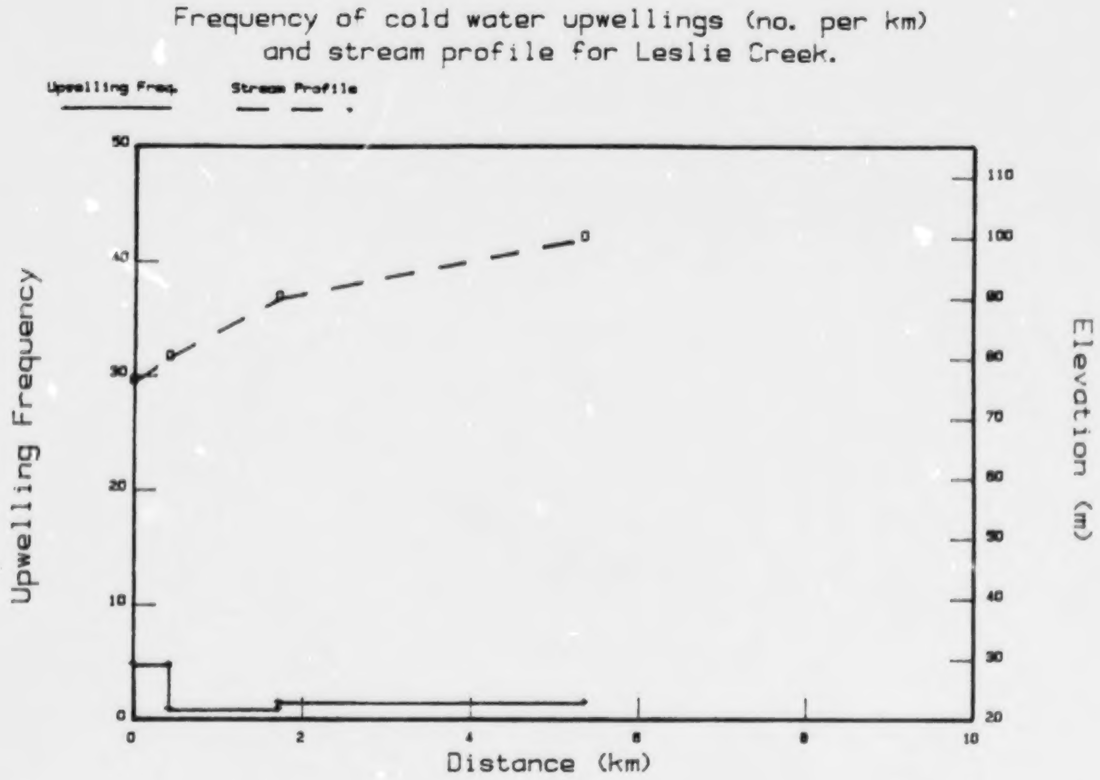


Figure 3: Stream profiles and associated frequencies of groundwater upwellings for Wilson And Sky Pilot Creeks.


Frequency of cold water upwellings (no. per km) and stream profile for Leslie Creek.

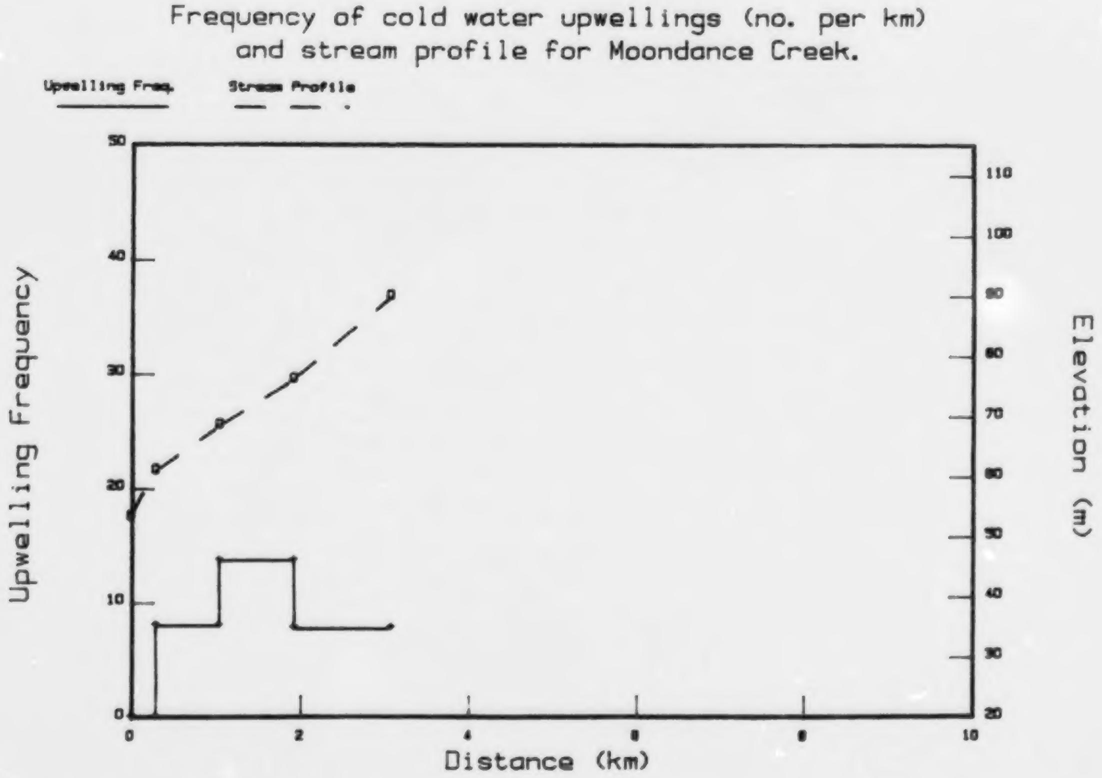
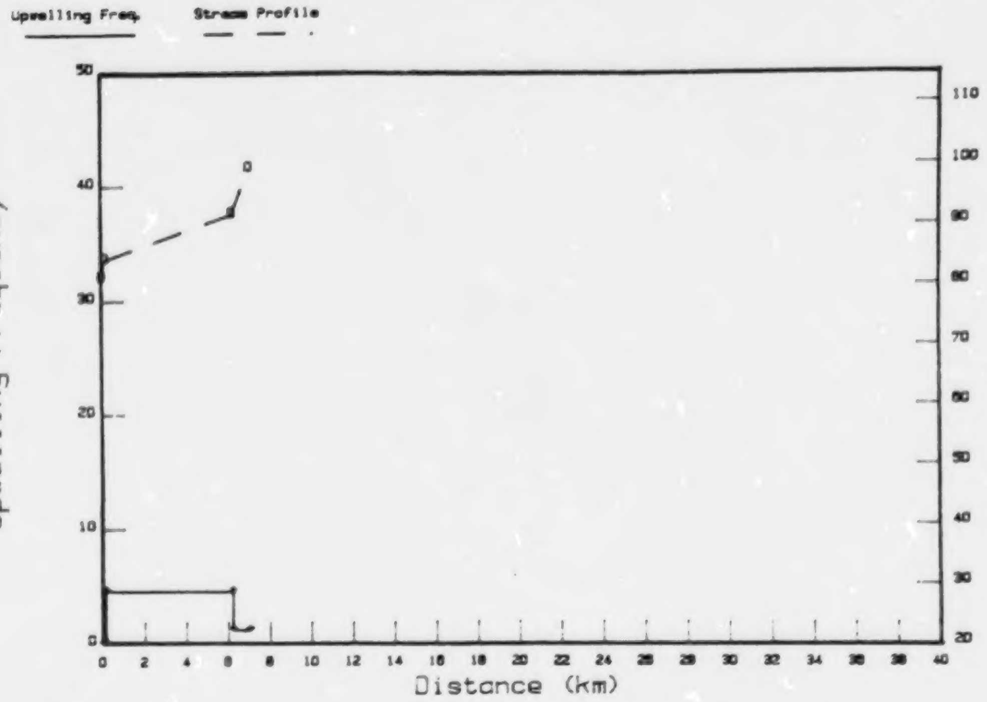

Frequency of cold water upwellings (no. per km) and stream profile for Moondance Creek.

Figure 4: Stream profiles and associated frequencies of groundwater upwellings for Leslie and Moondance Creeks.

Frequency of cold water upwellings (no. per km) and stream profile for 9-Mile Creek.



Frequency of cold water upwellings (no. per km) and stream profile for 12-Mile Creek.

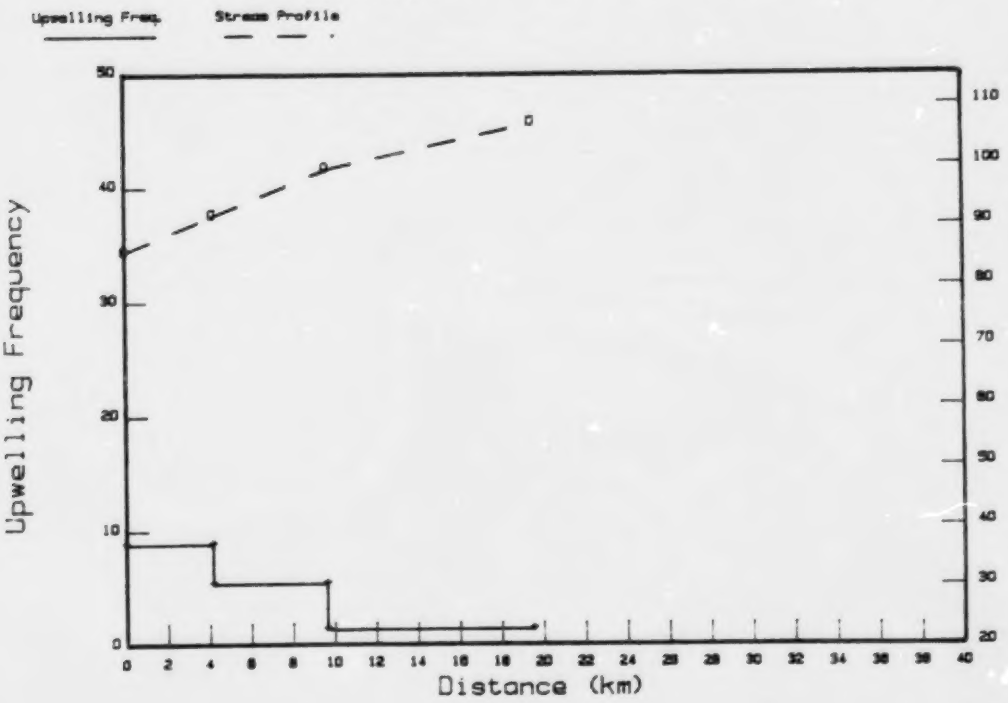


Figure 5: Stream profiles of groundwater upwellings for 9-Mile and 12-Mile Creeks.

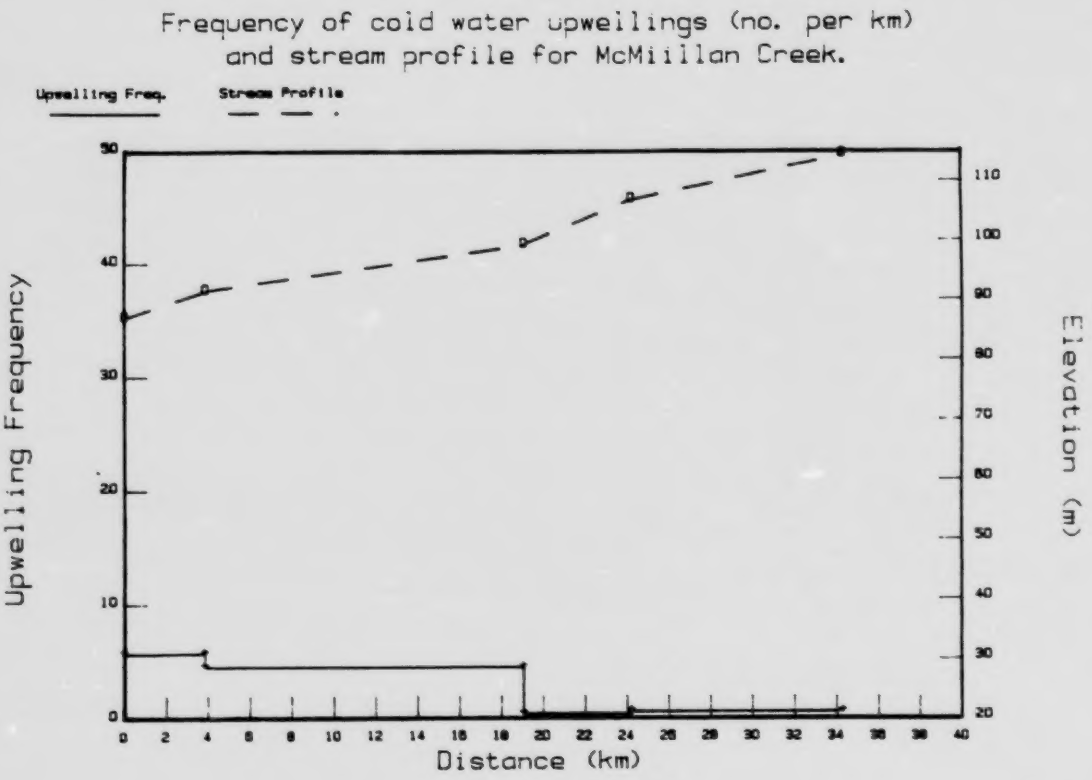


Figure 6: Stream profile and associated frequencies of groundwater upwellings for McMillan Creek.

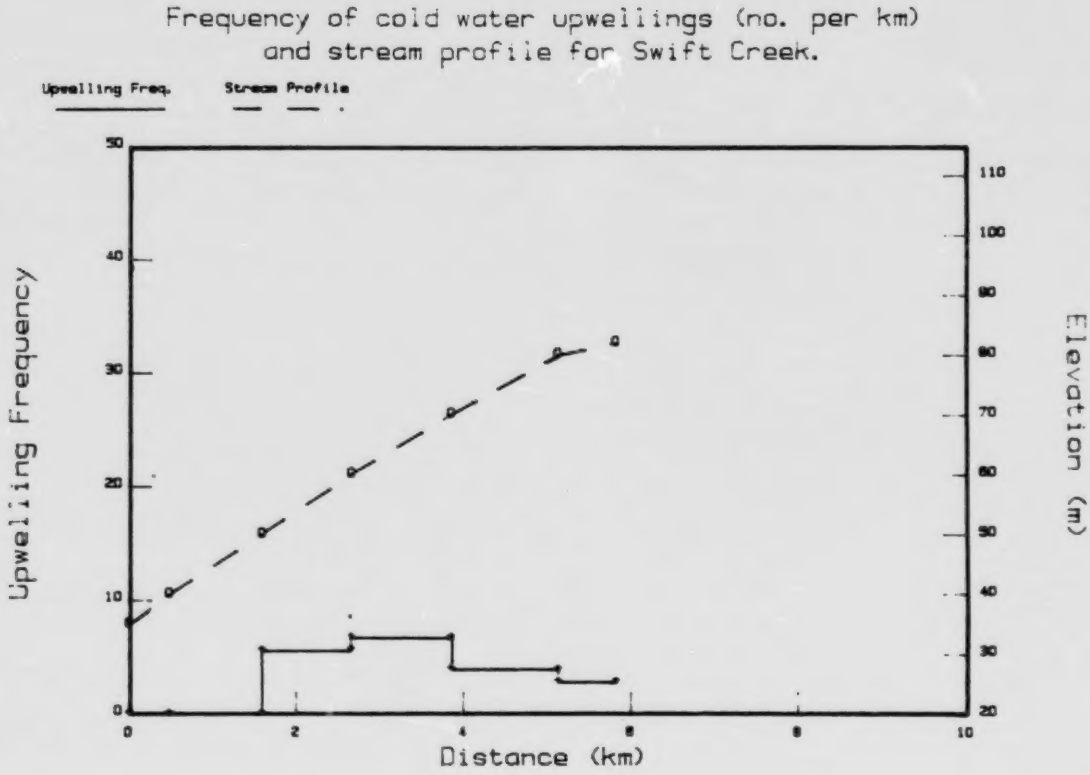


Figure 7: Stream profile and associated frequencies of groundwater upwellings for Swift Creek.

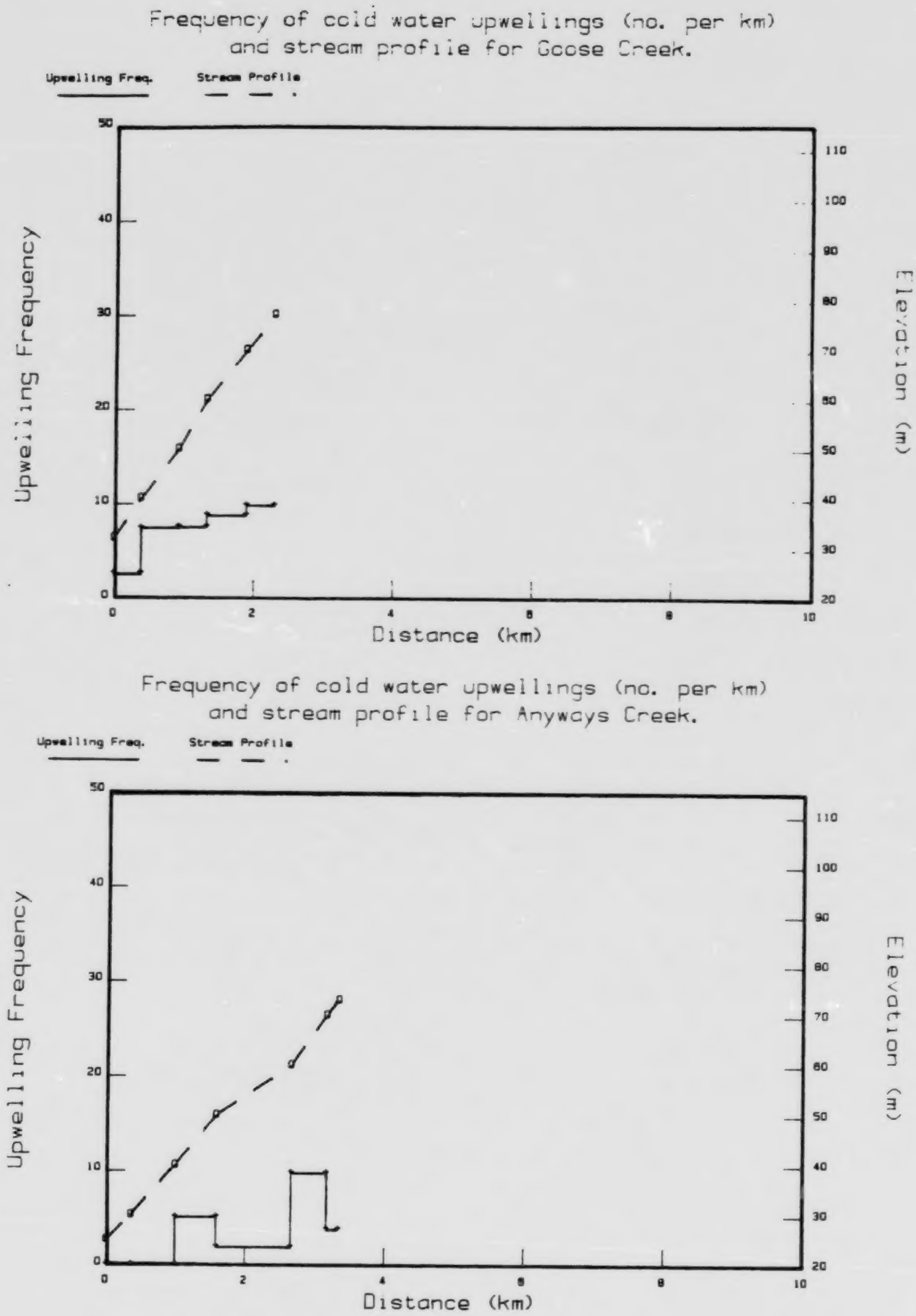


Figure 8: Stream profiles and associated frequencies of groundwater upwellings for Goose and Anyways Creeks.

Areas exhibiting peak groundwater upwelling frequencies were not always correlated with known brook trout spawning areas. Sky Pilot, Wilson and Leslie Creeks all had downstream areas which FLIR determined to have the greatest concentration of groundwater upwellings while the known spawning area for each stream were some distance upstream (Figure 9). It should also be noted that while peak groundwater influences were downstream from spawning areas on Wilson and Sky Pilot Creeks, FLIR did locate groundwater upwellings at both spawning sites. Spawning and peak groundwater upwelling frequency were more closely related for Limestone River tributaries (Figure 10). While McMillan Creek has unknown spawning contribution, both 9-Mile and 12-Mile known spawning pools were within the contour exhibiting the highest concentration of groundwater upwellings. Similarly, the groundtruth data for CN Creek indicated spawning in the area of strongest groundwater influence (Figure 10). The only known spawning area in those downstream tributaries surveyed was on Moondance Creek and was closely associated with FLIR's location of strongest groundwater influence (Figure 11). Other tributaries have unknown spawning areas and contribution within them, although the contribution is believed to be small.

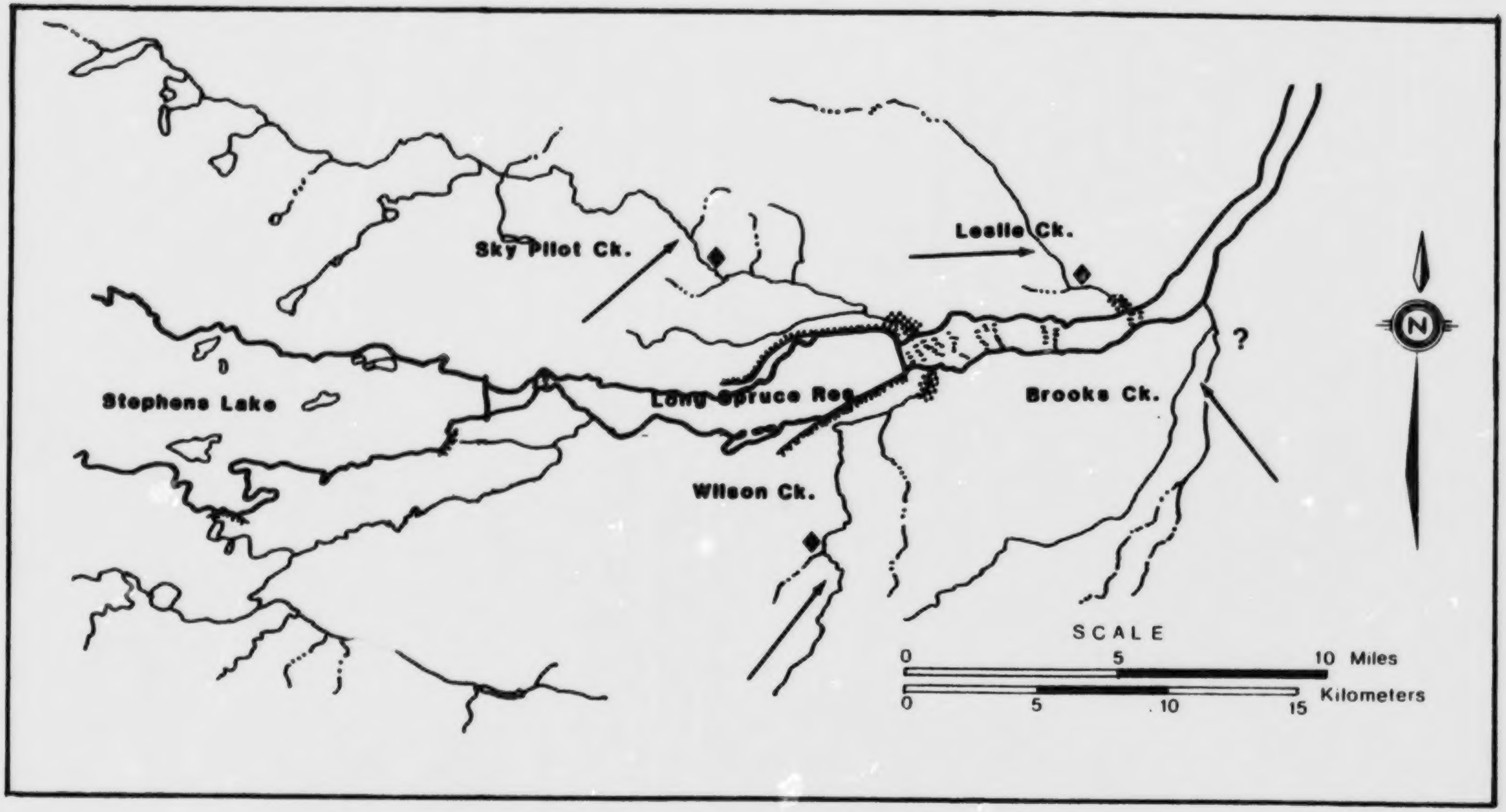

Sky Pilot Ck.
Leslie Ck.
Stephens Lake
Long Spruce Res.
Brooks Ck.
Wilson Ck.
?
N
SCALE
0
5
10 Miles
0
5
10
15
Kilometers

Figure 9: Location of peak groundwater upwelling frequency as determined by FLIR for Limestone Forebay tributaries. Diamonds indicate known spawning areas, question marks indicate unknown spawning and arrows indicate the upstream limit of the FLIR survey.

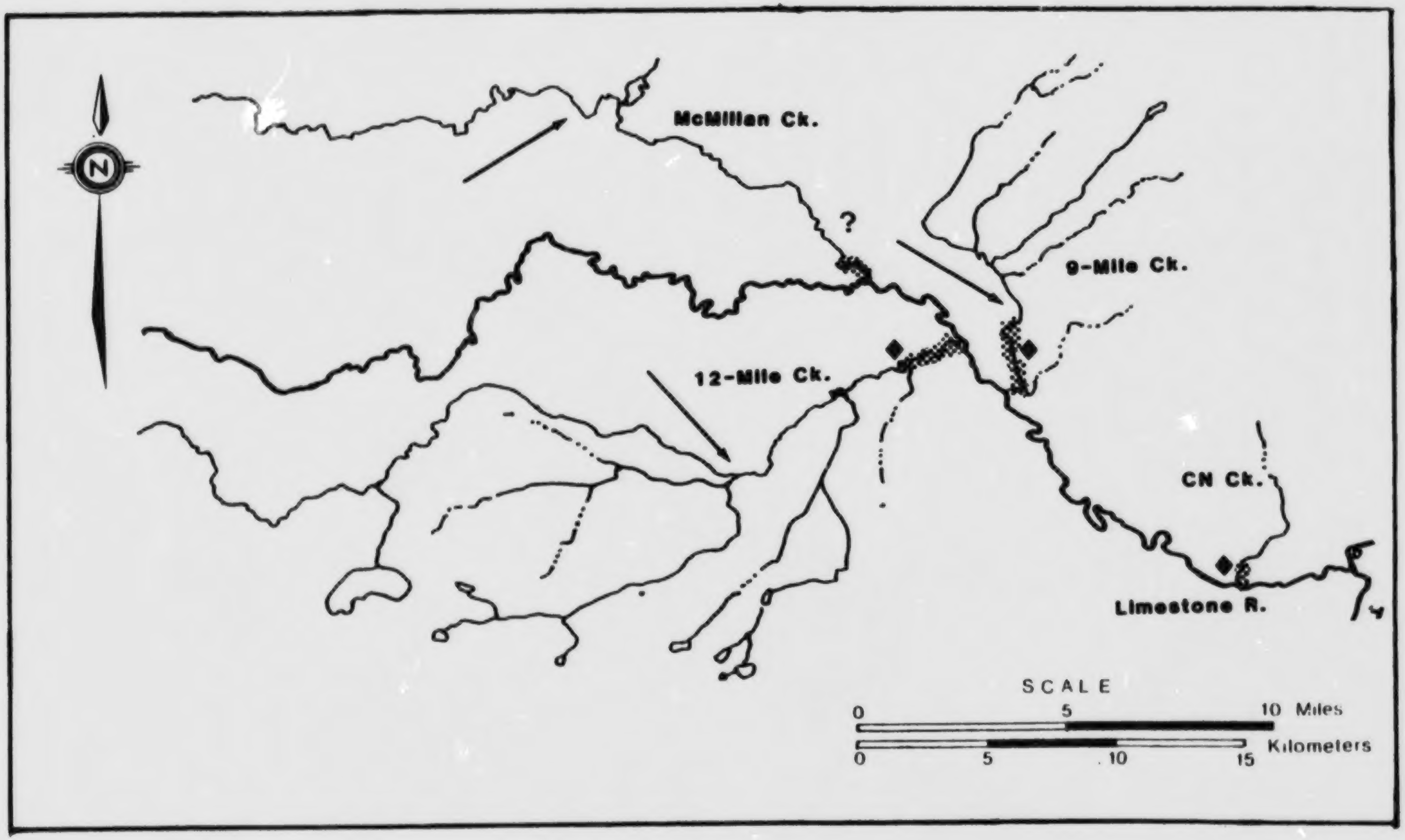

N
McMillan Ck.
?
9-Mile Ck.
12-Mile Ck.
CN Ck.
Limestone R.
SCALE
0
5
10 Miles
Kilometers
0
5
10
15

Figure 10: Location of peak groundwater upwelling frequency as determined by FLIR for Limestone River tributaries. Diamonds indicate known spawning areas, question marks indicate unknown spawning and arrows indicate the upstream limit of the FLIR survey. CN Creek data are groundtruth data.

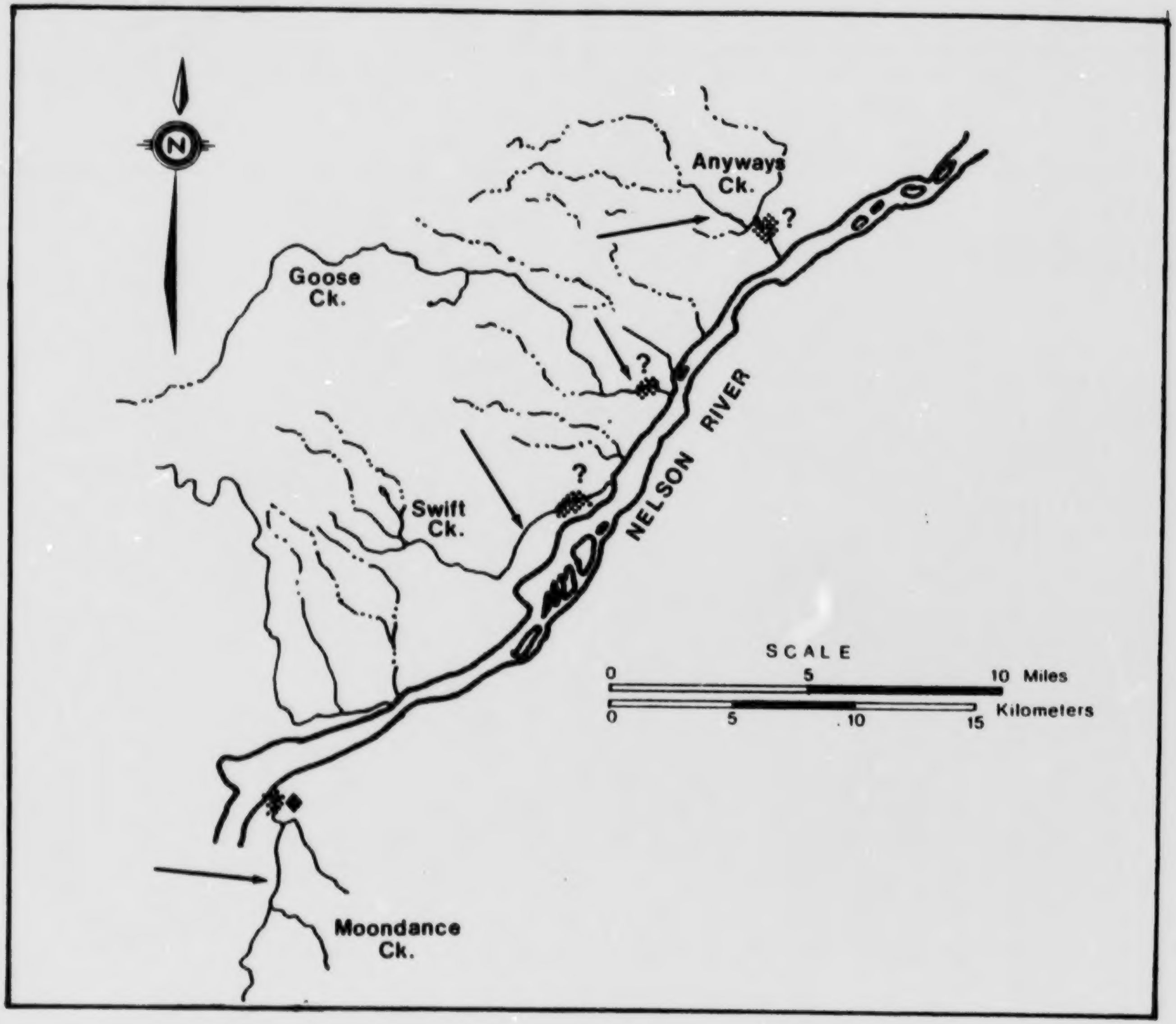

N
Anyways Ck.
?
Goose Ck.
?
?
NELSON RIVER
Swift Ck.
SCALE
0
5
10 Miles
0
5
10
15 Kilometers
Moondance Ck.

Figure 11: Location of peak groundwater upwelling frequency as determined by FLIR for remote downstream tributaries. Diamonds indicate known spawning areas, question marks indicate unknown spawning and arrows indicate the upstream limit of FLIR surveys.

DISCUSSION

Problems were encountered with the use of FLIR for surveying groundwater in streams. Small tributaries with abundant canopy cover could not be satisfactorily surveyed because overhanging vegetation effectively blocked large stretches of stream surface area from FLIR. Consequently CN, Beaver and Tiny Creeks could not be surveyed at all. At times canopy cover on larger tributaries (i.e. 9-Mile, Sky Pilot, etc.) interferred significantly with thermal sensing of surface water.

Navigation also proved to be a problem. Without numerous unique landmarks (eg. bridges, roads, etc.) determining exact locations, both while surveying and later on the videotaped imagery, was difficult. This was magnified by the use of different VCR's for the field survey and image analyses (DFO's portable VCR battery pack failed and a VCR was rented). Consequently tape count measurements used as field bench marks marked on NTS maps were not directly comparable to those used in the office. Finally, the combination of operator manipulation of the FLIR device and helicopter piloting was not sufficient to always maintain the stream in view of the FLIR at the altitude flown. As a consequence, unless one was extremely familiar with the stream being surveyed, pinpointing coldwater upwelling sites exactly was very difficult. Even so, navigation on a larger scale was not severely limited. Tributary streams and high banks located on both FLIR imagery and NTS maps served as reference boundaries between which coldwater upwellings were plotted.

Stream hydraulics also played a role in the detection of groundwater by FLIR. Very cold groundwater springs (as cold as 2°C) were undetected without extremely diligent assessment of FLIR imagery. This was because springs were often overgrown with vegetation and themselves therefore not visible. Moreover, the colder and denser groundwater sank rapidly if it entered the stream in gentle glide or pool habitat and remained undetected, perhaps to be observed downstream a riffle. This implies that low gradients should reduce the efficiency of FLIR by providing gentler slopes and more pool and glide habitat. No evidence was found to support this as no relationship between gradient and frequency of coldwater upwellings could be inferred. It is of interest to note that beaver dams were often associated with coldwater upwellings located by FLIR and with groundwater as determined using the electronic thermometer.

It is therefore believed that while site specific location of of coldwater upwellings was at times not possible due to a combination of stream hydraulic modification of coldwater upwellings and navigational difficulties, the assessment of coldwater upwellings on a more regional level (i.e. contour intervals) provided legitimate indications of the groundwater contributions in those streams surveyed. It should be noted however that a recent servicing of DFO's FLIR revealed a leak in a vacuum chamber in the device (Dave Barber, E.M.S.I. Ltd. per. comm.). This translates into lost sensitivity of the FLIR device while stream surveys were being done. To put this in perspective, the loss in sensitivity was sufficient to have prevented detection of ringed seal birthing layers with FLIR in 1987 a chore easily accomplished after servicing in 1988 (Dave Barber, E.M.S.I. Ltd. per. comm.).

Groundtruthing data on CN Creek located most groundwater sites in the 69-76 m contour interval (Figure 12). This corresponds to the peizometric level of about 72 m discovered near 5-Mile on the Limestone River in 1983 (information from Manitoba Hydro's Bird 1 topography and location of exploratory holes maps; Crippen Acres Engineering). Likewise, this corresponds to a CN Rail gravel pit which probably serves as an unconfined aquifer for groundwater discharge into CN Creek. Thus a relationship between groundwater, brook trout spawning areas and aggregate borrow is established for CN Creek. Similarly, Moondance Creek peak frequency of coldwater upwellings was in the 69-76 m interval at 13.7 per km (Figure 13). This also corresponds to: a peizometric level of 74 m (Manitoba Hydro data), a brook trout spawning area and proposed Manitoba Hydro aggregate borrow areas and temporary road crossing. On a larger scale potential granular borrow areas are often closely associated with groundwater discharge areas (Figure 14).

It is again of interest to note that a large beaver dam is located just below the spawning area in the peak groundwater upwelling contour interval in Moondance Creek. The dam is over 2m high and its location below groundwater upwellings provides beaver and brook trout alike with a considerably higher volume of habitat with year round water flow from spring activity.

Groundwater is gravitational in type (Figure 15) and gravel deposits act as the unconfined aquifers. The presence of gravitational springs also explains the simple relationship between creek mouth and peak upwelling elevation (Figure 2). Gravity maintains the water table at a more or less constant level above the aquitard in the glacial tils

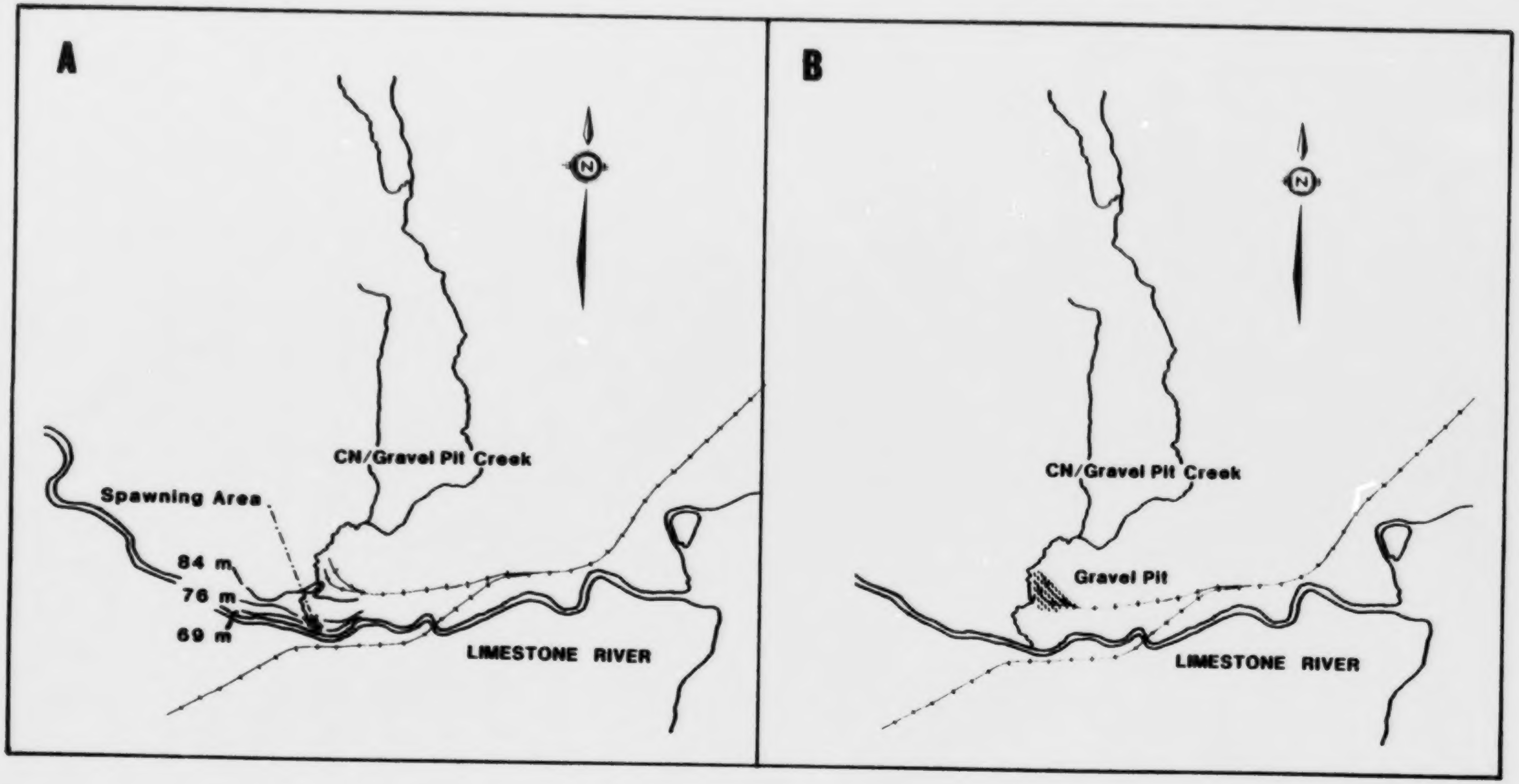

A
B
CN/Gravel Pit Creek
Spawning Area
84 m
76 m
69 m
LIMESTONE RIVER
CN/Gravel Pit Creek
Gravel Pit
LIMESTONE RIVER
N

Figure 12: CN Creek spawning area and contour intervals (A) and location of CN Rail's granular borrow area (B).

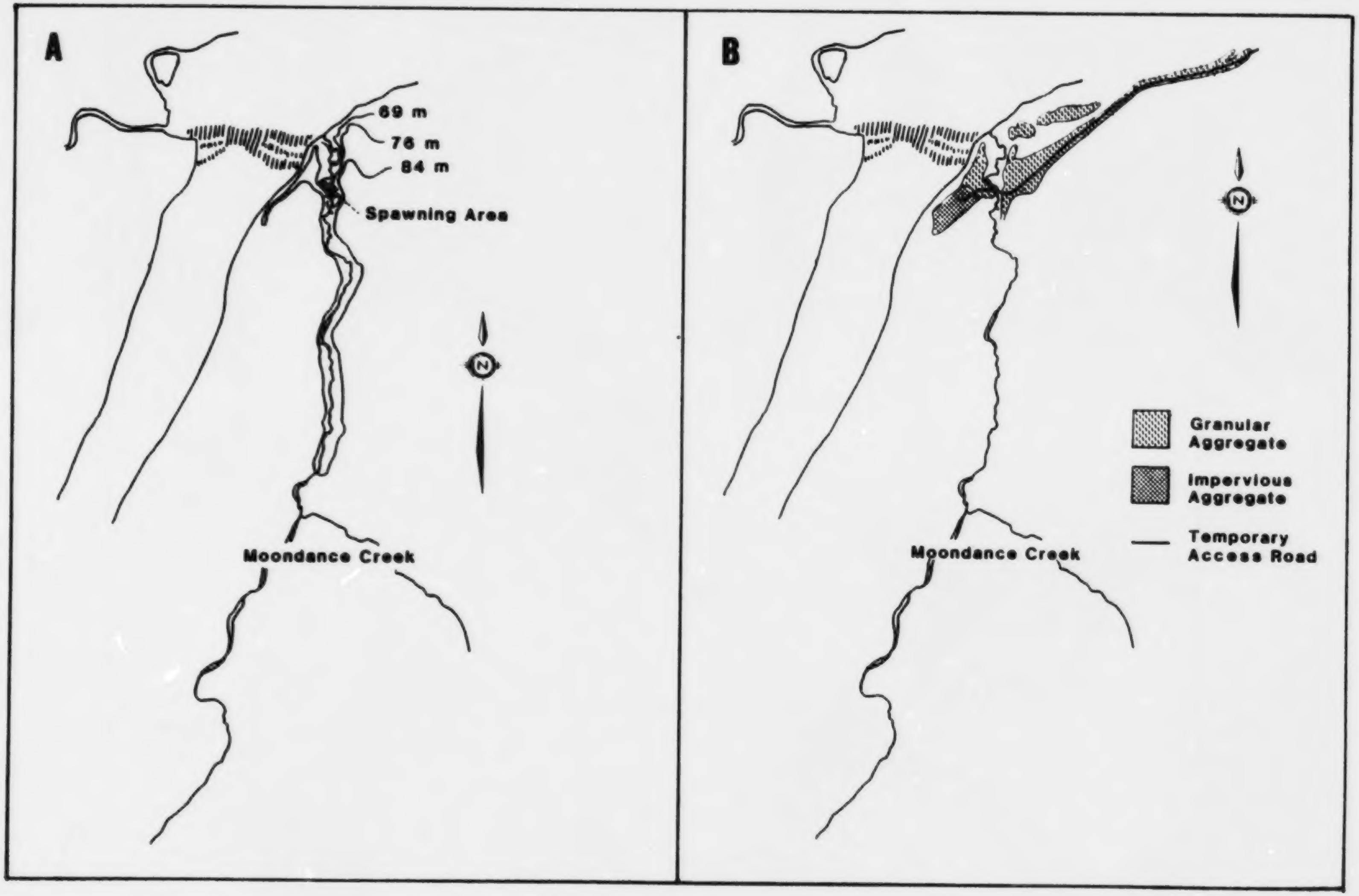

A
69 m
76 m
84 m
Spawning Area
Moondance Creek
N
B
Moondance Creek
N
Granular Aggregate
Impervious Aggregate
Temporary Access Road

Figure 13: Moondance Creek spawning area and contour interval (A) and location of proposed Manitoba Hydro borrow areas and access road (B).

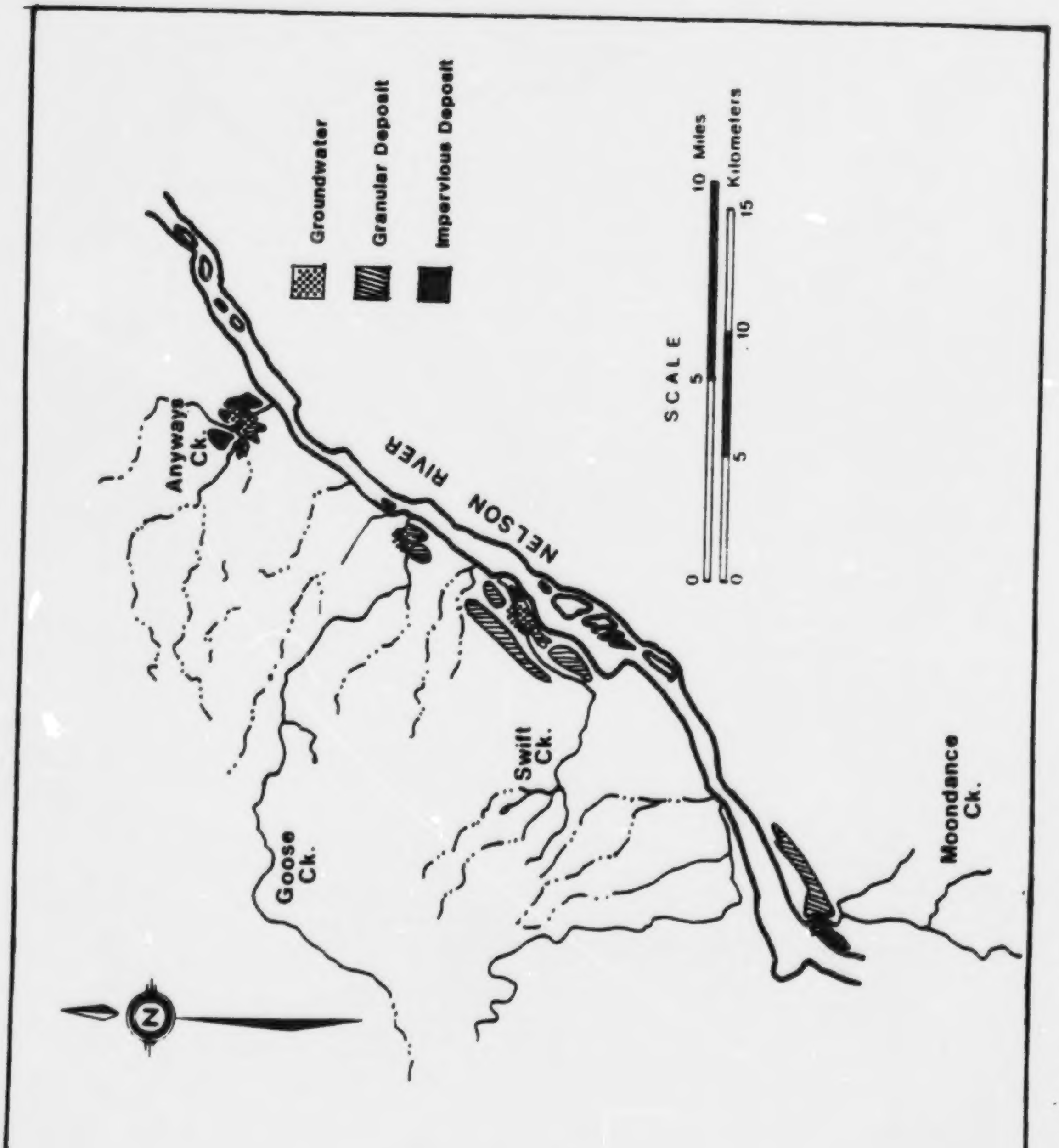

Groundwater
Granular Deposit
Impervious Deposit
SCALE
0
5
10 Miles
0
5
10
15 Kilometers
Anyways Ck.
NELSON RIVER
Swift Ck.
Goose Ck.
Moondance Ck.
N

Figure 14: Locations of groundwater discharge areas, potential granular borrow areas and potential impervious borrow areas.

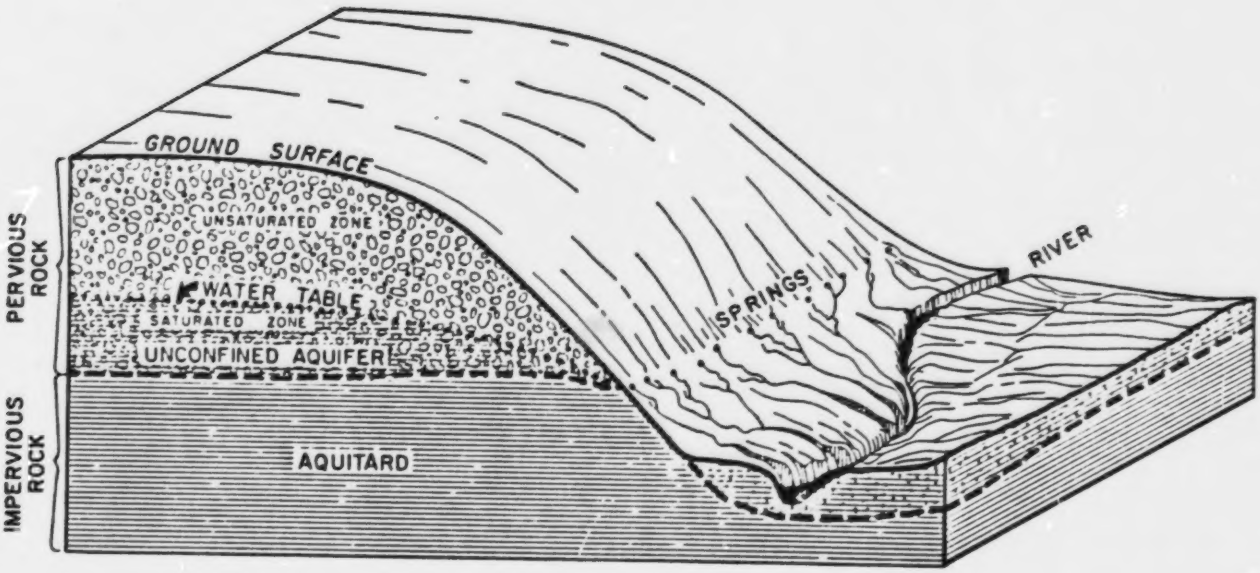

GROUND SURFACE
PERVIOUS ROCK
UNSATURATED ZONE
WATER TABLE
SATURATED ZONE
UNCONFINED AQUIFER
IMPERVIOUS ROCK
AQUITARD
SPRINGS
RIVER

Figure 15: Gravity springs (from Rutilus 1985).

overlying bedrock in this transitional zone between The Precambrian Shield and the Hudson Bay Lowlands.

The difference between groundwater contribution in smaller tributaries in the Conawapa Forebay and larger trout tributaries is a function of overall stream geomorphology. Because small streams transverse the water table over shorter distances fewer upwellings are present and overwintering habitat for eggs and/or juveniles is limited. Moreover, their smaller drainage basins results in higher gradients and therefore faster currents and reduced cover in groundwater areas. This translates into unsuitable spawning habitat for large spawning adults (Raleigh 1982). Therefore while the frequency of FLIR located groundwater upwellings per kilometer of stream was not different for Nelson River tributaries in the Conawapa Forebay than for Limestone River and Limestone Forebay tributaries their absolute frequency for the most part was (Appendix 4). Thus less influence was exerted with respect to stream temperature, making the habitat less suitable for trout in general. Moreover, high gradients result in decreased stream habitat volumes and therefore result in utilization by only small immature brook trout.

Management Implications

The use of FLIR for mapping sensitive brook trout habitat was somewhat limited. For the reasons previously discussed navigation under the 1987 field conditions was difficult. These problems could however be largely rectified by: flying at two times the elevation, using a recently serviced FLIR device and, using the same VCR for survey and analysis. Moreover, by physically measuring the stream temperatures represented on FLIR imagery and digitizing the imagery a more detailed assessment of the characteristics of groundwater upwellings may be obtained than from the more subjective visual assessment of FLIR imagery (D. Barber, EMSI Ltd., pers. comm.). In this regard, more work is required to refine the use of FLIR for indentifying site specific groundwater upwellings. In fact, those sites of primary interest (ie. brook trout spawning pools) while being associated with groundwater were not distinguishable from dozens of other "groundwater upwellings" which the FLIR located and which are not brook trout spawning areas.

With respect to more regional applications, FLIR did allow for location of stream reaches most likely to have their groundwater resources impacted with future development of the lower Nelson River. Existing and proposed habitat impacts in the lower Nelson River watershed are often in direct geographical proximity to areas of groundwater upwelling in stream habitat. Examples of this for past borrow areas include: CN Creek gravel pit and the F-Pit granular borrow area near Wilson Creek. Future access roads and borrow pit areas which conflict with groundwater upwellings in streams include: the Moondance Creek temporary crossing, the Conawapa Access Road, the Bird borrow site near 5 Mile on the Limestone River, borrow sites A-9 and A-10-1 near Moondance Creek and the numerous borrow pits and access roads located along the north shore of the Nelson River in the Conawapa Forebay area (Appendix 4). The potential therefore, to disrupt or alter fisheries habitat is significant when considering these developments.

Potential impacts associated with aggregate borrow and groundwater are: increased stream discharge peaks (Curtis in Dyer and Curtis in 1977), immediate and delayed changes in iron concentrations and water quality (Dyer and Curtis 1977) and dewatered water tables (McClymonds 1985). Moreover, stream crossing impacts relating to groundwater may include: changed iron and heavy metal concentrations in groundwater through the use of de-icing salt (Bowlby et al. 1987) and reduced suitability of groundwater habitat by placing crossings on or too close to groundwater upwellings. Finally, pollution of groundwater through fuel spills in borrow areas which serve as groundwater recharge areas could contaminate stream water supplies for a considerable period of time. Therefore, and because groundwater is critical to survival of first year brook trout, steps must be taken to avoid disrupting groundwater flows or adversely impacting its quality.

CONCLUSIONS

1. The FLIR device would probably have better served the study objectives with a few modifications.

2. Groundwater activity in the tributaries of the Nelson River appears to be gravitational in nature.

3. While brook trout spawning is not always located in the contour interval (1:50,000 NTS maps) with the _most_ apparent groundwater activity it does occur in areas of groundwater upwelling.

4. Development of aggregate borrow areas and access roads is to some extent in conflict with the integrity of groundwater in the area.

RECOMMENDATIONS

1. Future studies using DFO's FLIR device should be experimental in nature until the system is satisfactorily refined.

2. Borrow area - groundwater conflicts should be minimized by:
    - i) not excavating below the water table,
    - ii) not refueling in borrow areas which could result in fuel spillage in groundwater recharge areas,
    - iii) not dumping oil of or other machinery lubricants in borrow/groundwater areas,
    - iv) maintaining sufficient buffer strips along streambanks.

3. Pre and post development groundwater flows should be monitored for an as yet undeveloped granular aggregate borrow pit. Groundwater quantity and quality should be assessed to determine the impacts of aggregate borrow on groundwater resources.

4. Access road - groundwater conflicts should be minimized by avoiding placement on or near groundwater upwellings.

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LAKE STURGEON

INTRODUCTION

Data collected on the Lower Nelson River in 1986 failed to determine population estimates for lake sturgeon (Acipenser fulvenus). Long term radio telemetry studies which continued through the winter and spring of 1987 showed that sturgeon are capable of movements up to 100 km in less than two weeks and utilize the lower Nelson River extensively. However, no definite movement strategy could be defined with the telemetry results to that date.

Considering these findings and the ongoing and proposed hydroelectric development of the lower Nelson River, studies were undertaken in 1987 with the following objectives: 1) to assess population abundance through mark-recapture sampling procedures and 2) to define spawning locations, habitat requirements and overall utilization of the lower Nelson River and its tributaries through continued monitoring of radio tagged sturgeon.

METHODS

General

The Lower Nelson River was netted from the proposed Conawapa Generating Station (B-axis) to approximately 20 km upstream of Gillam Island. "Sturgeon gangs" each consisted of four panels of gillnets 25 m long and 2.5 m deep. Mesh sizes used were 7.6 cm., 12.7 cm, 22.9 cm and 30.5 cm. stretch measure. Each standard gang set was to be accompanied by a 30 m set line with 25, #9 hooks baited with sucker meat. This technique was used in an attempt to calibrate the relative catchability of the two gears so setlines could be used in areas where currents were too strong for gillnetting. Setline use was discontinued due to a zero success rate after several attempts. Gillnet set locations are shown in Figure 1.

A vigorous four-part sampling schedule was planned in 1987 in an attempt to make closed population abundance estimates using mark-recapture methods. Unfortunately, our outboard motor was severely damaged in June and was not available for use until September. This cut short our first trip (June 19-26) by a few days and eliminated two more netting sessions (July and August). Moreover, gillnetting in September proved to be ineffective due to extreme net fouling from algae drifting downstream in the Nelson River.

Sturgeon captured were sampled for total length, fork length and weight. Pectoral fin spines were removed for age determination as per Wilson (1987) and to assess growth (Sunde 1961). Back-calculations were made on fin sections with well defined annuli and aged on a

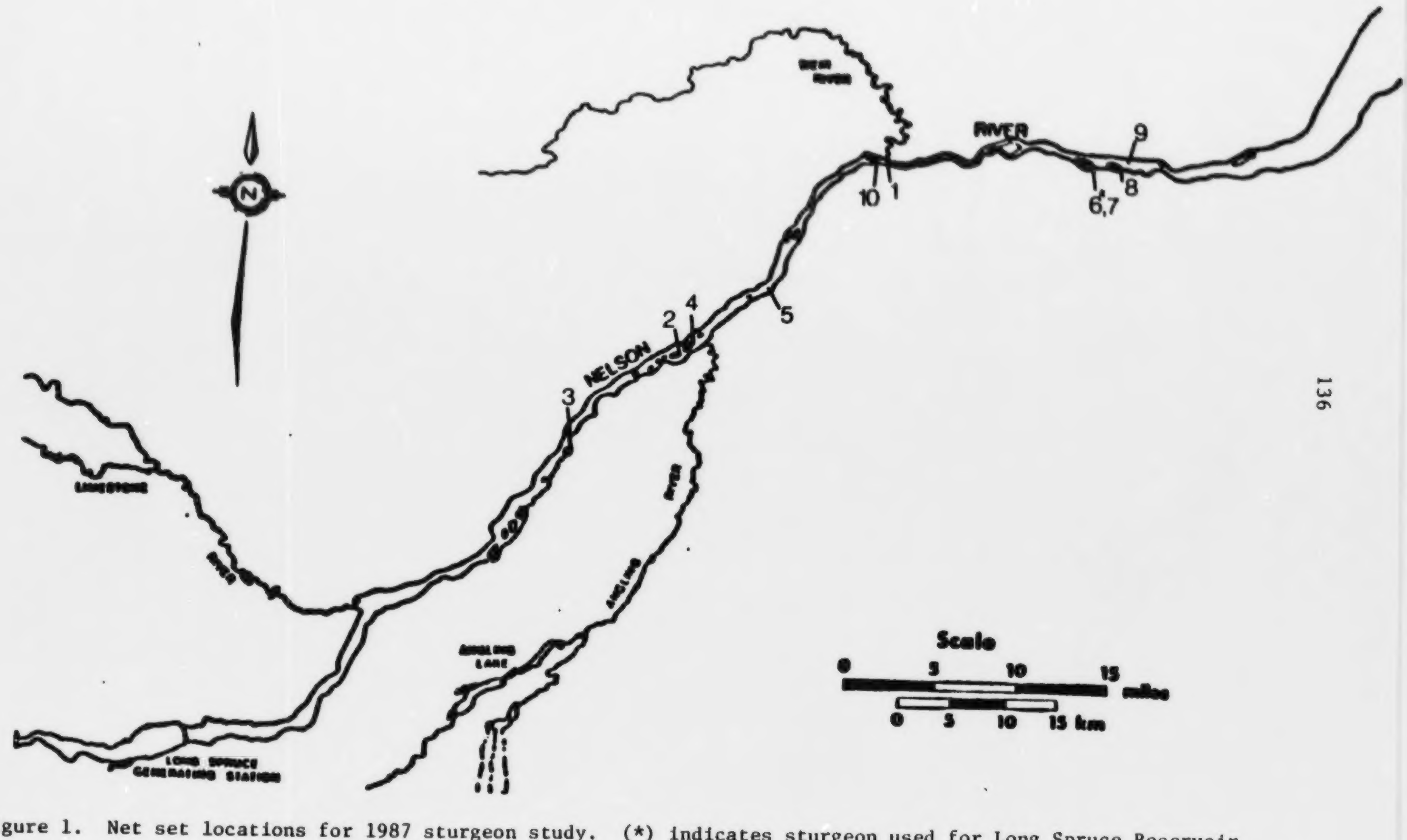
N
WEIR RIVER
RIVER
NELSON
10
1
9
8
6,7
5
4
2
3
LIMESTONE
RIVER
ANGLING RIVER
ANGLING LAKE
LONG SPRUCE GENERATING STATION
Scale
0
5
10
15
miles
0
5
10
15 km

Figure 1. Net set locations for 1987 sturgeon study. (*) indicates sturgeon used for Long Spruce Reservoir transfer.

microfiche viewer at 72X magnification.

Numbered disc tags were attached to the caudal fin of each sturgeon sampled along with a Floy spaghetti tag immediately below the dorsal fin for use as a double mark. All sturgeon were handled with nylon gloves and wounds resulting from fin clipping were treated with isopropyl alcohol to minimize infection.

Additional species were caught in association with the sturgeon gangs. All species were individually sampled for length and weight. Walleye (Stizostedion vitreum vitreum), northern pike (Esox lucius) and lake whitefish (Coregonus clupeaformis) were sampled for sex and maturity. For ageing, otoliths and dorsal spines were removed from walleye, otoliths were removed from whitefish and cleithra were taken from northern pike.

Angling Lake

Sturgeon were captured, sampled and released during the Angling Lake Inventory (see Part 5). Sampling procedures, ageing and growth analysis were identical to those for Nelson River sturgeon except for the tagging procedure which was omitted. Age, size and growth of Angling Lake sturgeon was compared to that for sturgeon caught in the Lower Nelson River in 1986 and 1987 combined.

Radio Telemetry

Sturgeon already tagged with 2-3 year life expectancy radio transmitters in 1986 (Swanson and Kansas 1987) were monitored by Fisheries Branch staff until fall 1987 and further tracked by Regional Services staff (Gillam/Sundance) through the winter of 1987/88. Tracking procedures continued as per Swanson and Kansas (1987) and tracking flights occured approximately every two weeks depending on aircraft availability and weather constraints.

Two sturgeon caught during the netting program in the lower Nelson River in 1987, as well as four from the Angling Lake Inventory, were transferred to the Long Spruce Reservoir and subsequently radio tagged. Data are presented in Appendix 5.

RESULTS

General

Two netting sessions were carried out (June 19-26 and September 6-10) in 1987. In total, 18 sturgeon were captured; 16 of which were tagged and released (Appendix 6) and two of which were transferred to Long Spruce Reservoir. Location captured, total length, weight and age are shown as well as the tagging information. All sturgeon tagged were released in excellent shape and swam away with vigor upon release. No recaptures were subsequently sampled. Catch per unit effort (CPUE) is shown in Table 1. All sturgeon were captured during the June 19-26 interval and ranged in size from 1.23 kg to 11.1 kg with a mean age of 23.5 years.

Fisheries Branch staff angled two sturgeon at the mouth of Moondance Creek with the following results:

date	total length (mm)	weight (kg)	age	comments
July 17	953	4.10	33	dead sample
July 30	772	1.90	31	tagged #0092

Back-calculated lengths of sturgeon were similar in 1987 to those calculated for the 1986 sample. Extensive analysis was not practical due to the small sample size in this years sturgeon catch results. Appendix 7 shows this comparison from fish aged back from 24 years to age 1. For each year, all fish were combined and the length was averaged out for each year. Figure 2 shows the length:weight

Table 1. Catch per unit effort (CPUE) data for individual sturgeon gangs in the Lower Nelson River in 1987. Actual numbers and kilograms caught are presented in parentheses.

Set #	Date (month . days)	Duration (hours)	CPUE (#/24hr)	CPUE (Kg/24hr)
1	06.19-22	72	1.33 (4)	3.20 (9.60)
2	06.19-20	24	9.00 (9)	16.90 (16.90)
3	06.22-24	48	0	0
4	06.23-25	48	0.50 (1)	0.75 (1.50)
5	06.24-26	48	1.50 (3)	5.70 (11.40)
6	06.26-29	72	0.33 (1)	11.10 (11.10)
7	06. 6-8	48	0	0
8	09. 6-8	48	0	0
9	09. 8-10	48	0	0
10	09. 8-10	48	0	0

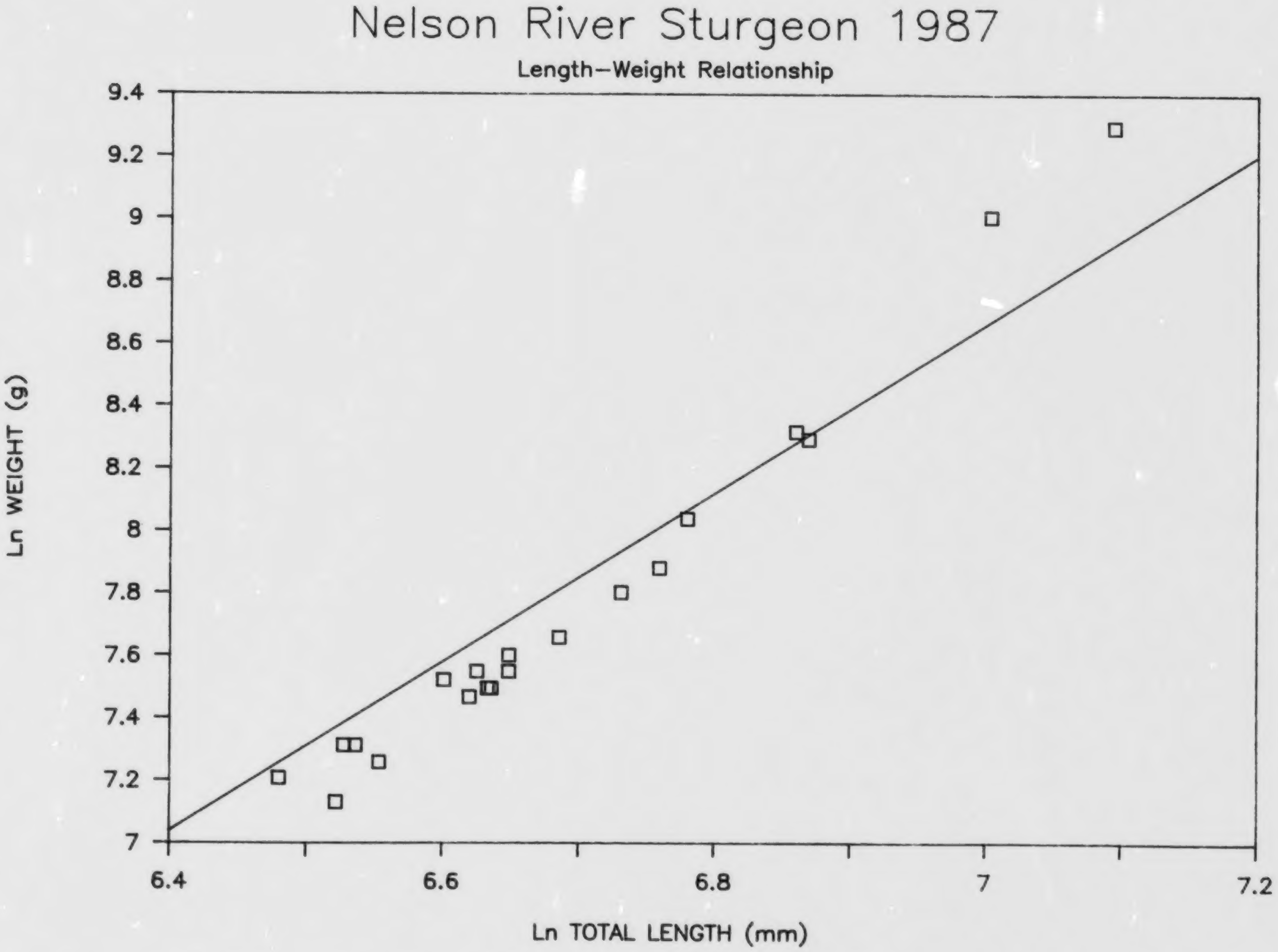

Figure 2: Nelson River 1987 lake sturgeon length/weight relationship.

relationship of the sturgon sampled (n=20).

Data for all species caught in 1987 experimental netting on the Nelson River are shown in Table 2. Since relatively few of each species were captured in the sturgeon gangs, only the number and total weight are shown. Northern pike were the most important species by weight and frequency and sturgeon were the second most important.

Angling Lake

Twenty-three sturgeon were sampled in Angling Lake during the inventory undertaken in 1987 (see Part 5). They ranged in size from 2.3 kg to 20.0 kg with a mean age of 36.3 years. Appendix 8 shows a comparison between Angling Lake data and 1986 and 1987 Nelson River data combined for back-calculated lengths. Likewise, Appendix 9 provides the comparison of the 1. sturgeon length and weight relationship for Angling Lake and the 1986 and 1987 Nelson River sturgeon. Angling Lake sturgeon exhibit very similar growth rates and length:weight relationships and a greater mean age.

Radio Telemetry

The following sturgeon movement information includes data collected since the 9 sturgeon were tagged with 3 year life expectancy radio transmitters in 1986. Each sturgeons movements are reported individually.

Tag frequency 48.042 Mhz, originally tagged below the Long Spruce Generating Station (L.S.G.S.) has utilized the area immediately below the dam since the first tracking report. This area includes from

Table 2. Gill net summary for all species caught in sturgeon gangs in the lower Nelson River in 1987 showing catch composition and total numbers and weights.

Species		Mesh size (cm)					
		7.6	12.7	22.9	30.5	Total	%
Lake sturgeon (*Acipenser fulvescens*)	no.	0	14	2	3	19	24.1
	kg.	0	25.3	12.2	16.9		30.9
Northern pike (*Esox lucius*)	no.	11	26	0	1	38	48.1
	kg.	13.7	91.7	0	2.9		61.6
Walleye (*Stizostedion vitreum*)	no.	1	1	0	0	2	2.5
	kg.	0.6	2.0	0	0		1.5
Lake whitefish (*Coregonus clupeaformis*)	no.	0	1	0	0	1	1.25
	kg.	0	1.2	0	0		0.8
Longnose sucker (*Catastomus catastomus*)	no.	18	0	0	0	18	22.8
	kg.	8.6	0	0	0		4.9
Burbot (*Lota lota*)	no.	1	0	0	0	1	1.25
	kg.	0.4	0	0	0		0.8
Total	no.	31	42	2	3	79	
	kg.	23.3	120.2	12.2	19.8	175.5	
	% no.	39.2	53.2	2.6	4.0		
	% kg.	13.3	68.5	6.9	11.3		

just below the dam to approximately 2 km downstream (Figure 3).

Tag frequency 48.717 Mhz was tagged just above the lower Limestone rapids on July 26, 1986 and 17 days later appeared downstream around Jackfish Island where it remained until October 22, 1986. This frequency was not located again until July 16, 1987 when it was found in the estuary where it has remained and was last located on October 3, 1987 (Figure 4).

Tag frequency 48.079 Mhz was tagged at the mouth of the Angling River on June 14, 1986. Eight days later it moved downstream to the estuary followed by movement back upstream to Jackfish Island by August 31, 1986 where it remained until May 2, 1987. On May 31, 1987 it was located back in the estuary and was not located again until July 16, 1987 where it was found in the Jackfish Island area (Figure 5).

Tag frequency 48.061 Mhz was tagged on June 14, 1986 at the mouth of the Angling River. Eight days later it was located in the estuary and 3 weeks later it was back upstream to a point 8 km up from Jackfish Island. By fall it had moved down to Jackfish Island. After not being locted all summer and for most of the fall, 48.061 was found on November 10, 1987 in Angling Lake, which is a headwater lake of Angling River (Figure 6).

Tag frequency 48.222 Mhz was tagged on June 17, 1986 at the mouth of the Angling River. It was located here again on June 22 and was not located again for over a year. On November 10, 1987 it was found in Angling Lake where it remained (Figure 7).

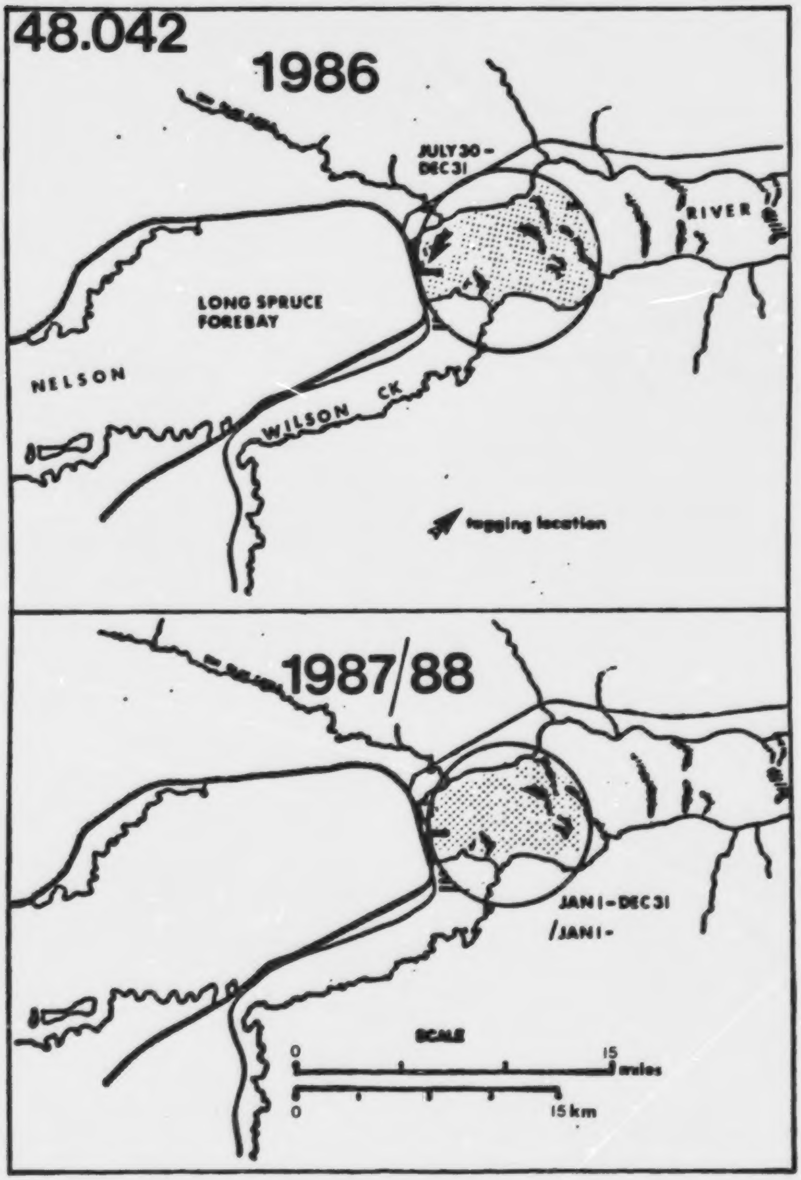
48.042
1986
JULY 30 -
DEC 31
RIVER
LONG SPRUCE
FOREBAY
NELSON
WILSON CK
tagging location
1987/88
JAN 1 - DEC 31
/JAN 1 -
SCALE
0
15
miles
0
15 km

Figure 3: Movements of lake sturgeon radio tagged 48.032 Mhz in 1986-87 and 1987-88.

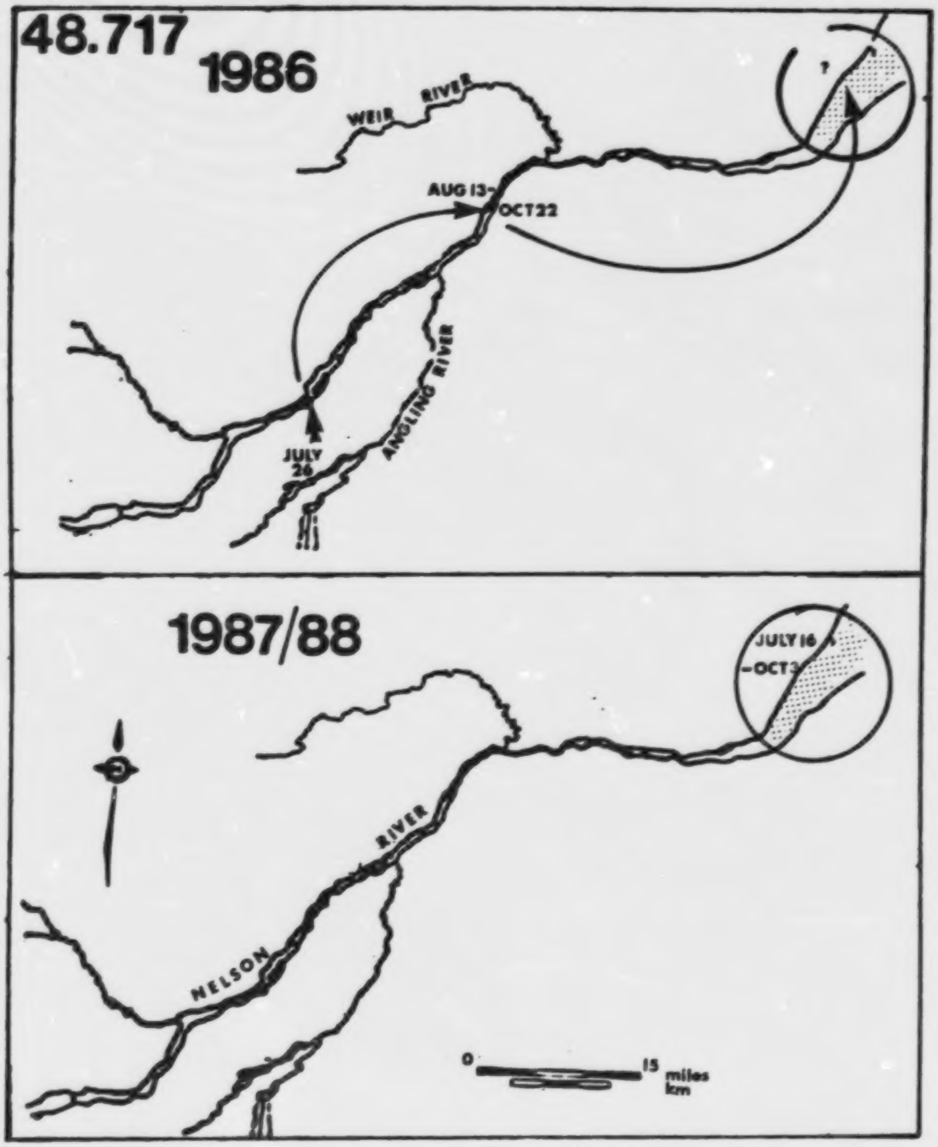
48.717
1986
WEIR RIVER
?
AUG 13-
OCT22
JULY 26
ANGLING RIVER
1987/88
JULY 16
-OCT3
RIVER
NELSON
0
15
miles
km

Figure 4: Movements of lake sturgeon radio tagged 48.717 Mhz in 1986-87 and 1987-88.

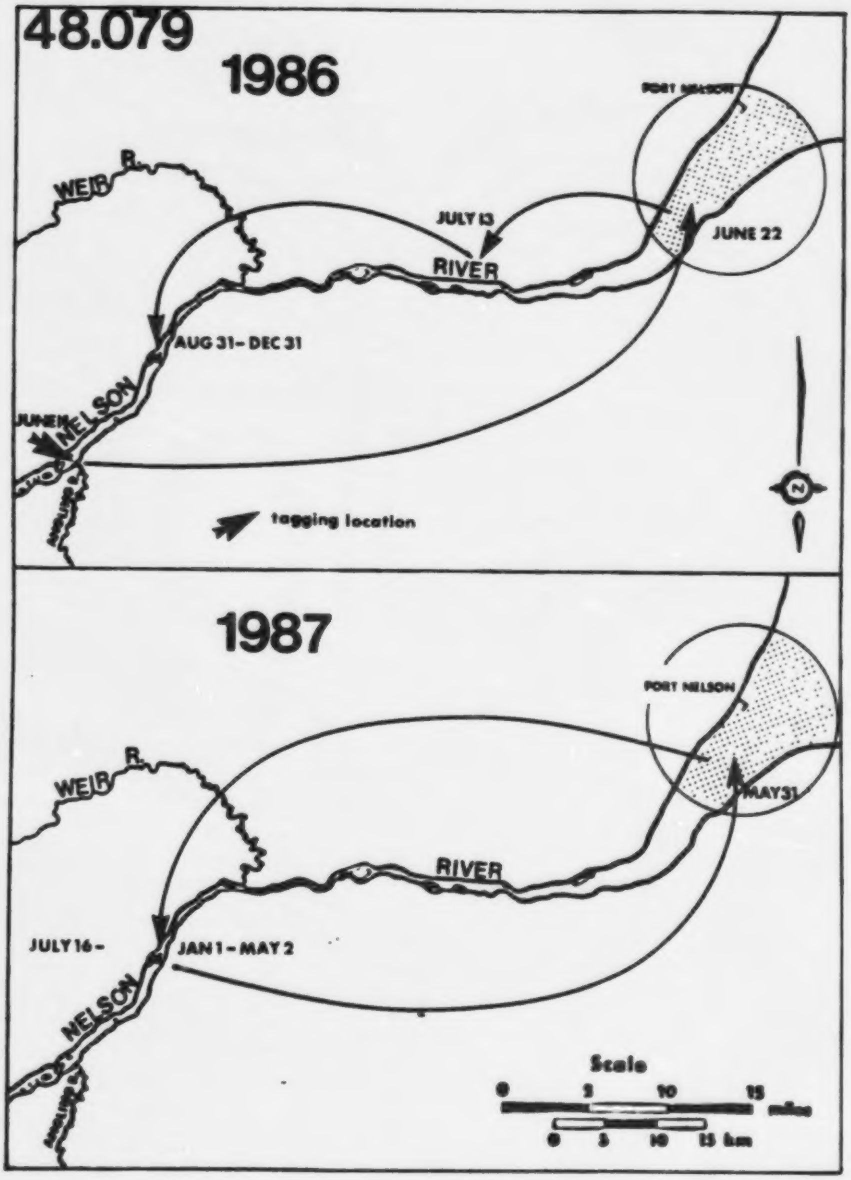
48.079
1986
PORT NELSON
WEIR R.
JULY 13
RIVER
JUNE 22
AUG 31 - DEC 31
JUNE 16
NELSON
ANGLING R.
tagging location
N
1987
PORT NELSON
WEIR R.
RIVER
MAY 31
JULY 16 -
JAN 1 - MAY 2
NELSON
ANGLING R.
Scale
0
5
10
15
miles
0
5
10
15 km

Figure 5: Movements of lake sturgeon radio tagged 48.079 Mhz in 1986-87 and 1987-88.

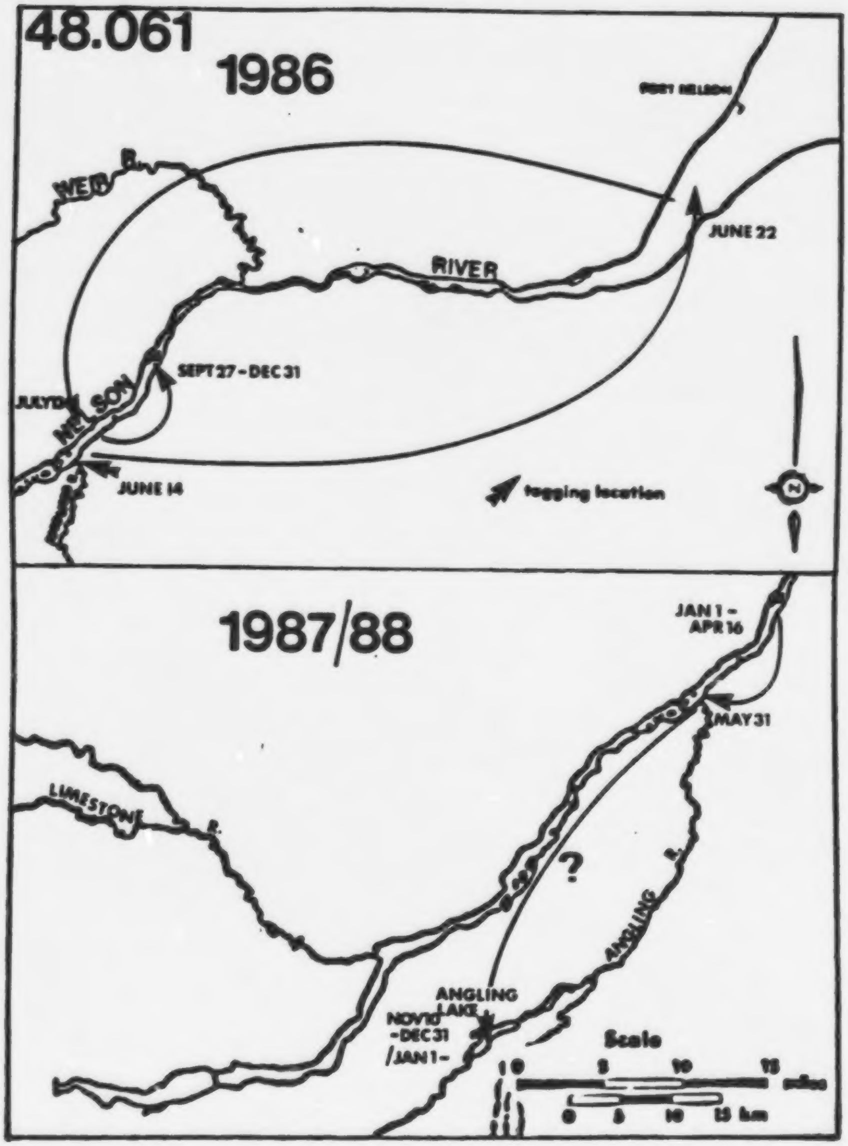
48.061
1986
PORT NELSON
WEB R.
RIVER
JUNE 22
SEPT 27 - DEC 31
JULY
NELSON
JUNE 14
tagging location
N
1987/88
JAN 1 -
APR 16
MAY 31
LIMESTONE R.
?
ANGLING R.
ANGLING
LAKE
NOV 10
-DEC 31
/JAN 1-
Scale
0
5
10
15
miles
0
5
10
15 km

Figure 6: Movements of lake sturgeon radio tagged 48.061 Mhz in 1986-87 and 1987-88.

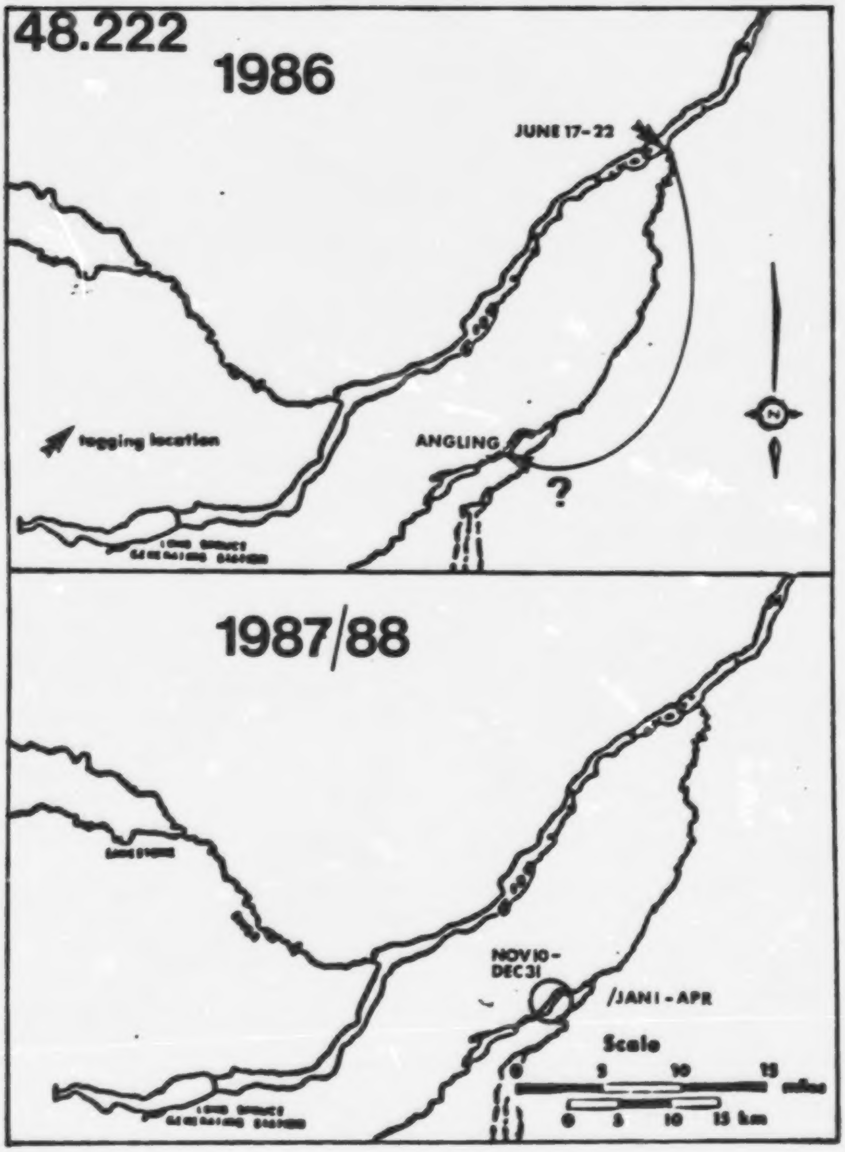
48.222
1986
JUNE 17-22
tagging location
ANGLING
?
1987/88
NOV 10 -
DEC 31
/JAN 1 - APR
Scale
0 5 10 15 miles
0 5 10 15 km

Figure 7: Movements of lake sturgeon radio tagged 48.222 Mhz in 1986-87 and 1987-88.

Tag frequency 48.022 Mhz was tagged at the mouth of the Weir River on June 16, 1986. Six days later it was located in the estuary and remained there until at least July 27, 1986. It started moving back upstream in mid August of 1986 and overwintered in the Jackfish Island area until March 31, 1987. On April 16, 1987 it moved downstream to Deer Island and eventually to the estuary by July 16, 1987. By September 3, 1987 this fish was back up to the Jackfish Island area and it remained there overwinter (Figure 8).

Tag frequency 48.102 Mhz was tagged at the mouth of the Weir River on June 16, 1986. It was located there again six days later and by July 13, 1986 was in the estuary. It has remained in the Nelson River estuary exhibiting localized movements until its last location date of November 28, 1987 (Figure 9).

Tag frequency 48.201 Mhz was tagged at the mouth of the Weir River on June 16, 1986. By July 27, 1986 it had moved into the estuary and has remained there until its last known contact of November 28, 1987 (Figure 10).

Tag frequency 48.151 Mhz was tagged at the mouth of the Weir River on June 16, 1986. Six days later it too was located in the estuary where it overwintered and remained until at least July 31, 1987. By September 3, 1987 it was back upstream to the Jackfish Island area and was located there again on September 17, 1987 which was its last location date (Figure 11).

Table 3 shows the total distances travelled by each fish. Localized movements such as tag 48.042 Mhz were not considered "movements" in this summary. All movements were greater than 15 km

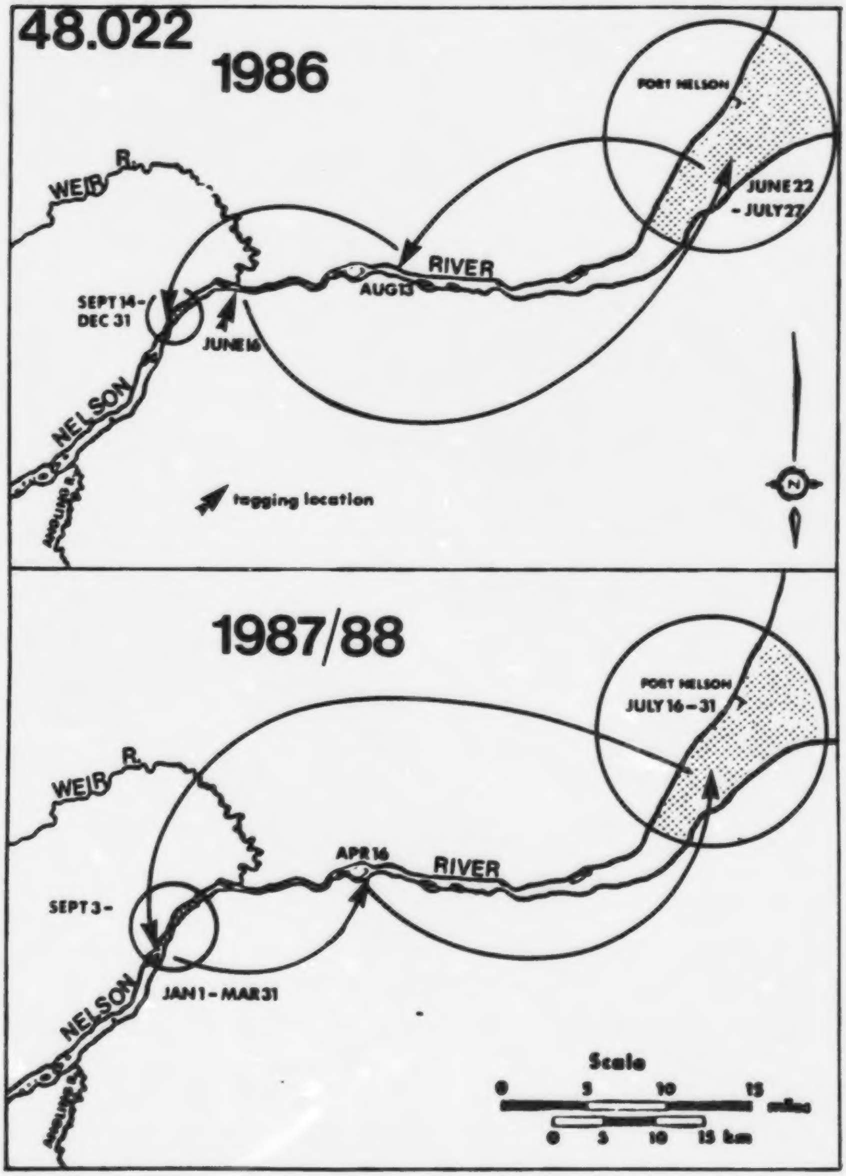
48.022
1986
WEIR R.
PORT NELSON
JUNE 22
- JULY 27
RIVER
AUG 13
SEPT 14-
DEC 31
JUNE 16
NELSON
tagging location
N
1987/88
PORT NELSON
JULY 16 - 31
WEIR R.
APR 16
RIVER
SEPT 3-
JAN 1 - MAR 31
NELSON
Scale
0 5 10 15 miles
0 5 10 15 km

Figure 8: Movements of lake sturgeon radio tagged 48.022 Mhz in 1986-87 and 1987-88.

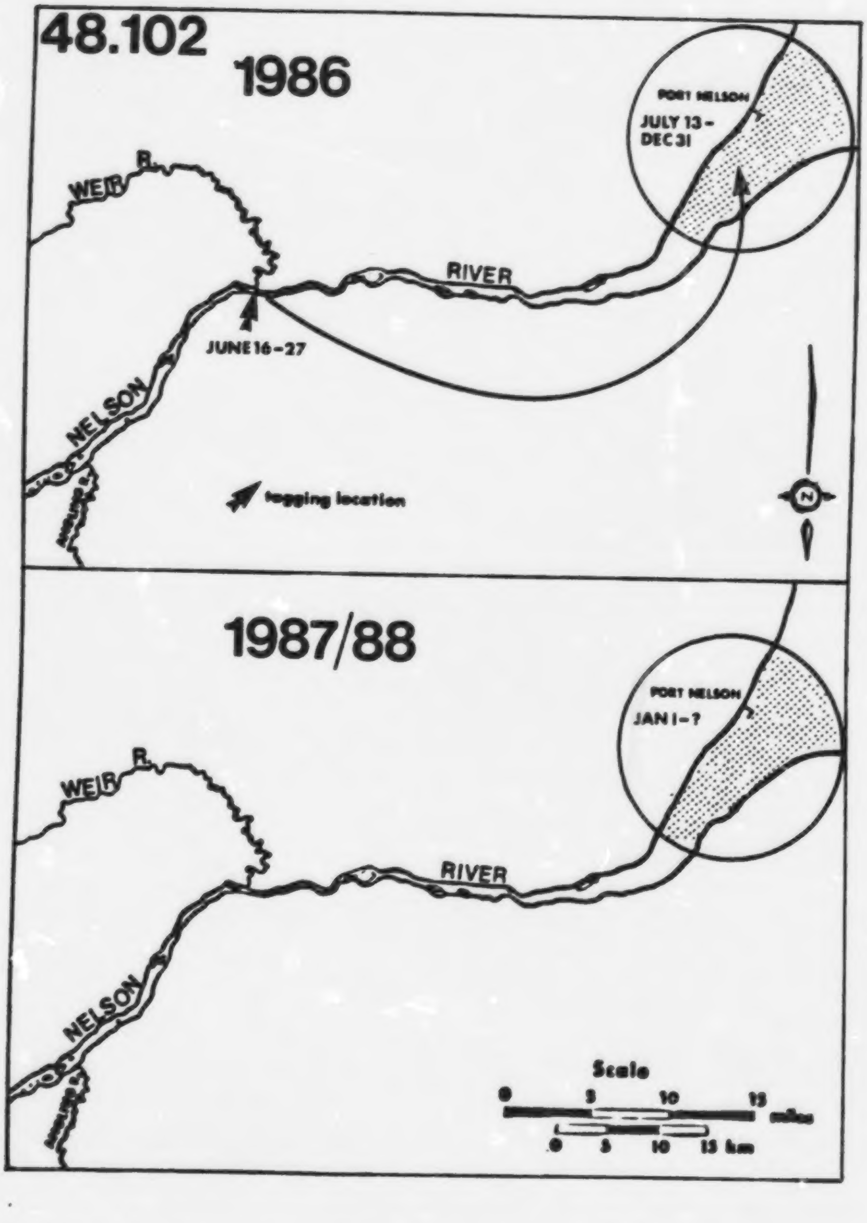
48.102
1986
FORT NELSON
JULY 13 -
DEC 31
WEIR R.
RIVER
JUNE 16-27
NELSON
tagging location
N
1987/88
FORT NELSON
JAN 1-?
WEIR R.
RIVER
NELSON
Scale
0
5
10
15
miles
0
5
10
15 km

Figure 9: Movements of lake sturgeon radio tagged 48.012 Mhz in 1986-87 and 1987-88.

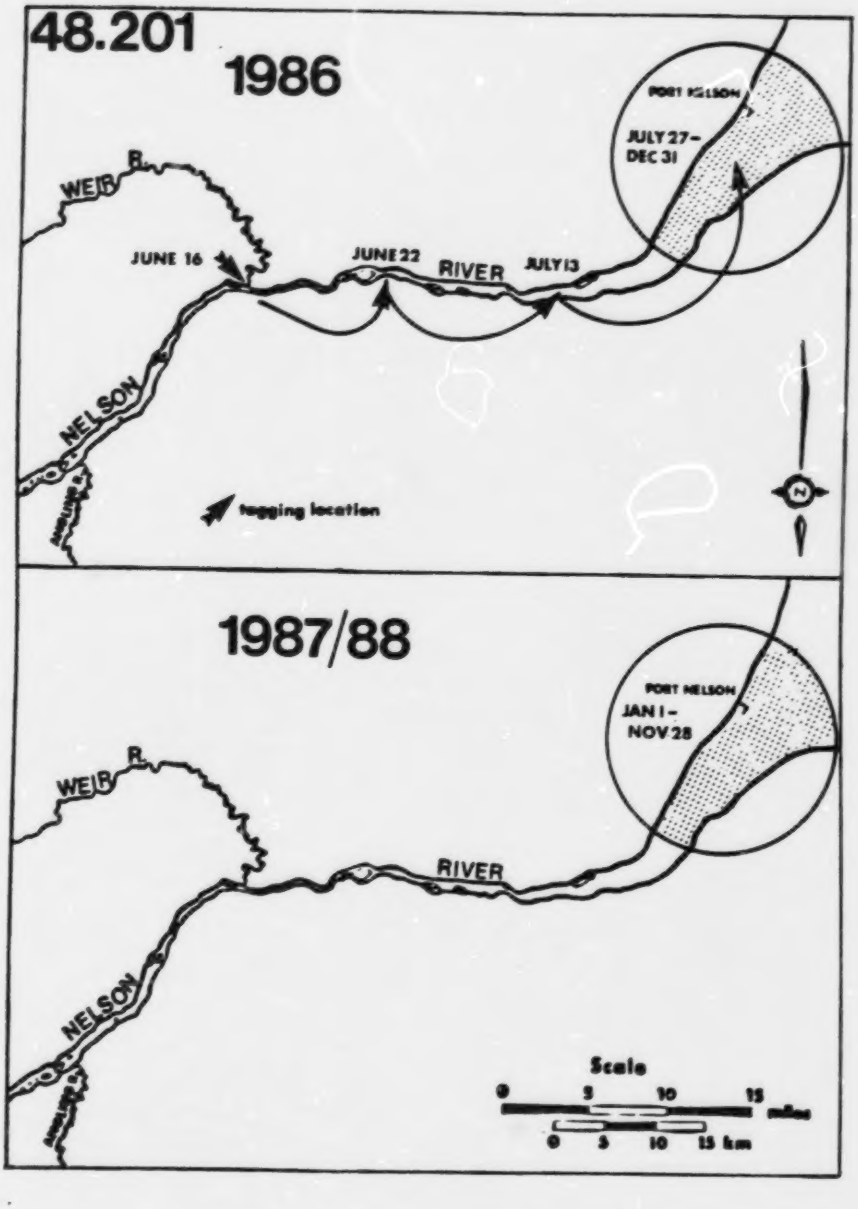
48.201
1986
WEIR R.
JUNE 16
JUNE 22
RIVER
JULY 13
PORT NELSON
JULY 27–
DEC 31
NELSON
tagging location
N
1987/88
WEIR R.
RIVER
PORT NELSON
JAN 1 –
NOV 28
NELSON
Scale
0
5
10
15
miles
0
5
10
15 km

Figure 10: Movements of lake sturgeon radio tagged 48.201 Mhz in 1986-87 and 1987-88.

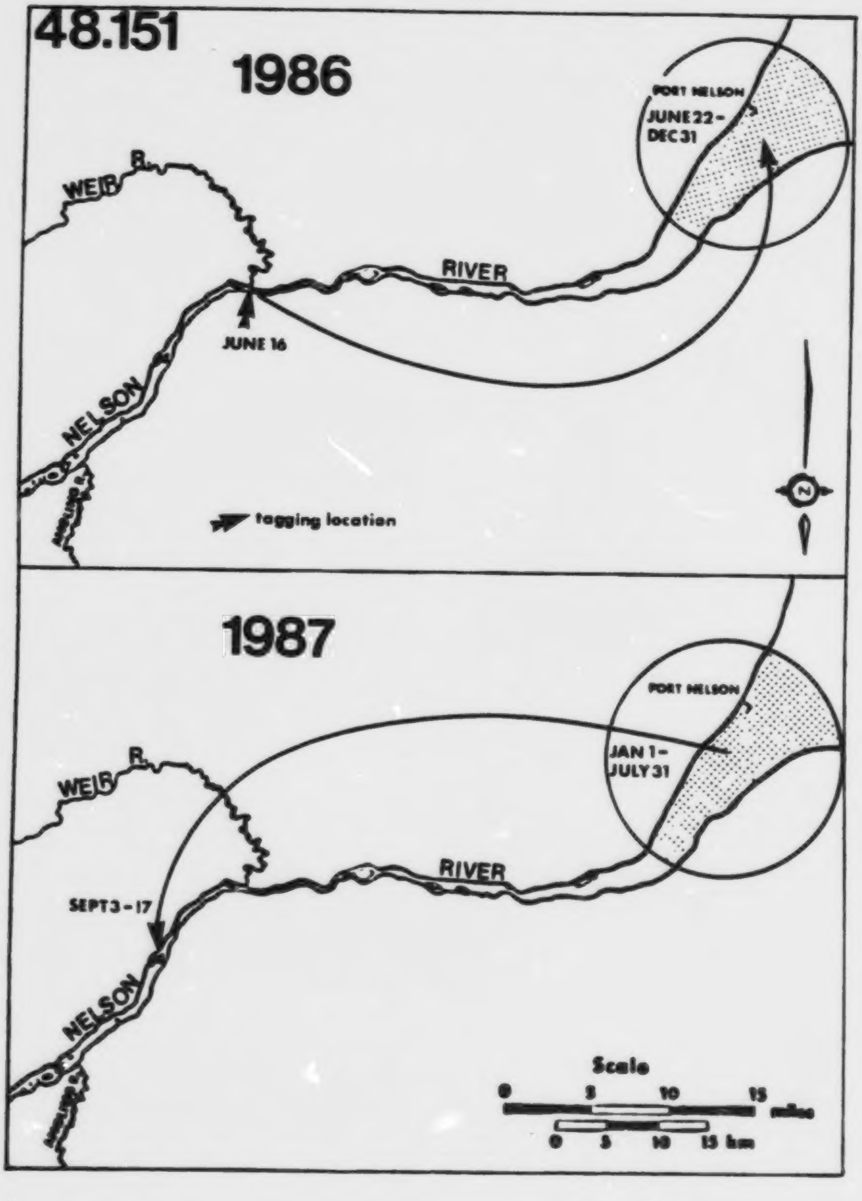
48.151
1986
PORT NELSON
JUNE 22-
DEC 31
WEIR R.
RIVER
JUNE 16
NELSON
tagging location
N
1987
PORT NELSON
JAN 1-
JULY 31
WEIR R.
RIVER
SEPT 3-17
NELSON
Scale
0 5 10 15 miles
0 5 10 15 km

Figure 11: Movements of lake sturgeon radio tagged 48.151 Mhz in 1986-87 and 1987-88.

Table 3. Movement summary of radio tagged lower Nelson River sturgeon showing total distances travelled both upstream and downstream.

Frequency	Tagging Location	Date Tagged	Downstream Movement (Km)	Upstream movement (Km)	Total movements (Km)
48.042	below L.S.G.S.	30.07.86	0	0	0
48.717	above lower Limestone rapids	28.07.86	110	0	110
48.222	mouth of Angling R.	14.06.86	0	55	55
48.061	mouth of Angling R.	14.06.86	84	140	224
48.079	mouth of Angling R.	14.06.86	145	130	275
48.151	mouth of Weir R.	16.06.86	45	65	110
48.102	mouth of Weir R.	16.06.86	45	0	45
48.201	mouth of Weir R.	16.06.86	45	0	45
48.022	mouth of Weir R.	16.06.86	125	115	240

(upstream or downstream). The following table shows the number of such movements observed in each season over the course of the monitoring program:

direction	1986		1987	
	summer	fall	winter	spring
Downstream	8	2	2	1
Upstream	8	0	0	3

Most of these movements occurred in the summer, usually in August and early September. The winter downstream movements were both in very late winter (April). The upstream spring movements were all associated with movements to the mouth of Angling River and up it to Angling lake.

Figure 12 highlights all capture locations of sturgeon over the two year test-netting program. As well it highlights areas where radio tagged sturgeon have overwintered and even places where they have staged year round (Area 5 for example). The arrows point out generalized direction and timing of movements between these proposed overwintering areas.

Of the six lake sturgeon transferred into the Long Spruce Reservoir-Kettle River system only one was consistently located within the system (tag frequency 48.218 Mhz). This tag was consistently located along the north dike near the Long Spruce Generating Station. Two other tags were consistently located in one spot each, downstream from the Long Spruce Generating Station; 48.179 Mhz consistently located near Leslie Creek and 48.240 Mhz located near the Weir River. Neither of these tags demonstrated any significant movement in any direction. The remaining three tagged sturgeon were not located again shortly after release.

DISCUSSION

Commercial exploitation and habitat loss through hydroelectrical development have been directly related to serious declines in sturgeon numbers in eastern Canada (Brousseau 1987, Payne 1987) and the United States (Graham 1984). Since the commercial fishery for sturgeon on the Lower Nelson River is not currently operating and has been very limited in the past decade (Swanson and Kansas 1987), a unique opportunity exists to study the effects of current hydroelectric development and previous dam construction on the sturgeon population in this area.

The Lower Nelson River sturgeon population abundance remains unknown. Population estimates were not possible because too small a sample size was collected to make valid estimates. The small sample size incurred in both field seasons (1986 and 1987) does not necessarily mean a small population of sturgeon exists. The reason being that data collection in the Nelson River in this particular study area, have suffered severe setbacks due to problems encountered in the sampling schedule (i.e. extreme net fouling by algae, strong water currents, water level fluctuation, motor problems, etc.). Therefore, a true picture of the sturgeon stock abundance remains unknown.

Comparisons of growth between sturgeon caught in 1987 with those in 1986 revealed similar rates. A lower mean age in 1987 was the result of using smaller mesh sizes than were used in 1986. Therefore growth data were combined for Nelson River sturgeon caught in 1986 and 1987 and compared to sturgeon caught in Angling Lake in 1987. This comparison also revealed similar rates of growth. This lends evidence to the theory that Angling Lake sturgeon are members of the Nelson River stock.

Sturgeon caught in Angling Lake are probably from the Nelson River. Angling Lake is a midwater basin of the Angling River. The Angling River flows into the Nelson River and is the only connection between Angling Lake and the Nelson River. During low flow periods the Angling River appears unnavigable due to the extremely low water levels. Conversely the time it appears most easily transversed is in the spring when flows are high due to spring runoff. Supporting this statement are the movements of two radio tagged sturgeon (48.022, 48.061 Mhz) which migrated up the Angling River in the spring of 1987 and now reside in Angling Lake. Priegel and Wirth (1971) found that sturgeon in the Wolfe River system migrate to and from Lake Winnebago during spawning migrations. Dumont et al. (1987) also noted migrations from the Saint-Laurent River to lakes connected to that river system. Therefore, based on similar growth rates and observed sturgeon movements Angling Lake and Lower Nelson River lake sturgeon are assumed to belong to the same stock.

Sturgeon movements in the Lower Nelson River as exhibited by two years of radio telemetry data are complex. Telemetry data illustrates that Lower Nelson River sturgeon exhibit both large movements, of up to 100 km, and sedentary behaviour with relatively no long migrations. Recent studies in Ontario and Quebec have also shown almost nil to extensive movements. Nowak and Jessop (1987) found relatively small movements (26 km) on sturgeon in the Mattagami River.

Sandilands (1987) found that sturgeon move as far as 150 km on the Kenogami River. These studies support our findings which illustrated the sometimes erratic movement pattern by sturgeon in the Lower Nelson River.

Lake sturgeon appear to summer in the confluence of the Nelson River and Hudson Bay and overwinter in the same area or in one of two other areas (Figure 12). Seven of the nine sturgeon radio tagged spent at least one summer in the estuary. Overwintering was frequently in the Nelson River with four of nine lake sturgeon overwintering at least once in the Nelson River between Angling River and Weir River inflows. This particular stretch of the Nelson River provides some of the deepest water as indicated in Manitoba Hydro survey data (unpublished data). This area may therefore provide sufficient water depth to overwinter lake sturgeon. Sturgeon in the South Saskatchewan River in Alberta tracked by radio telemetry showed a preference for deep channel portions of the river (C. McLeod, Rivers, Lakes & Lands, pers. comm.). Other noted overwintering areas include the estuary and Angling Lake. Of those sturgeon which overwintered at least once in the estuary one subsequently moved back up the Nelson River indicating that it was alive. This negates mortality or tag loss as an explanation for their observed presence in the estuary year round. To date the significance of Angling Lake to the life history of Nelson River lake sturgeon is largely unknown.

Most activity occurs during the summer months. This summer movement could be the result of foraging behaviour. This may illustrate utilization of the river as a "highway" in the active search for food

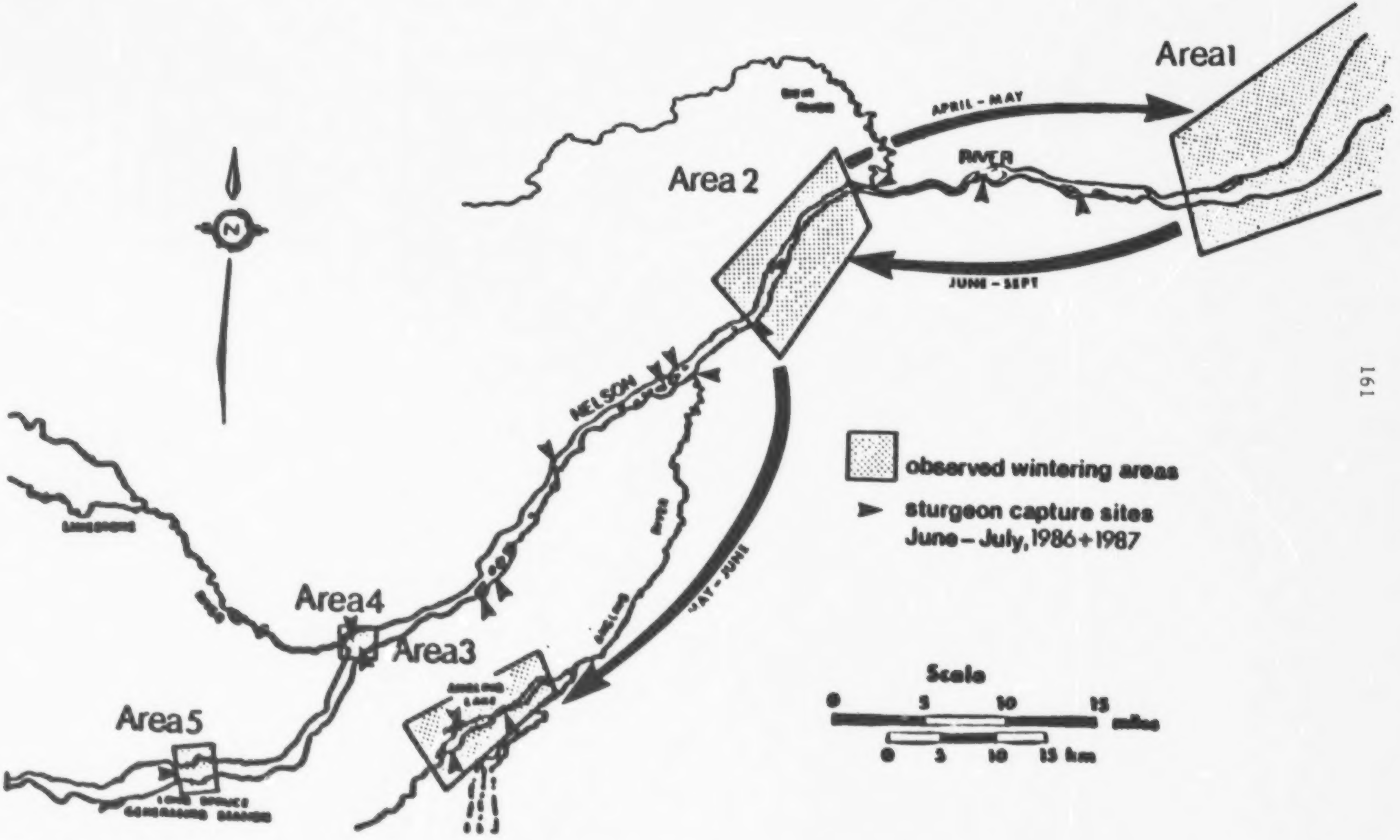
Area1
Area 2
Area3
Area4
Area5
APRIL - MAY
JUNE - SEPT
MAY - JUNE
RIVER
NELSON
observed wintering areas
sturgeon capture sites
June – July, 1986 + 1987
Scale
0
5
10
15
miles
0
5
10
15 km
N

Figure 12: Capture sites on the Lower Nelson River during 1986-87 testnetting and observed overwintering areas for radio tagged sturgeon. Solid arrows indicated observed movements to and between wintering areas.

in the summer months. Nowak and Jessop (1987) found similar mid-summer movements in the Groundhog River in Ontario. Movements there occurred after the spawning period.

Utilization of Area 5 which is immediately below the L.S.G.S., suggests that this one fish has found a "nirvanna" type setting. The best combination of food availability, wintering habitat and spawning area might have been found, as well as a permanent barrier to upstream migrations. It is interesting to note that this sturgeon (48.042 Mhz) was the heaviest fish for its length of all sturgeon sampled to date. This may be the result of a quality food base and lack of movement. Didiuk (1975) stated sturgeon were observed feeding on dead fish below the Kettle Dam and that spawning may occur in the tailrace section, which contains artificial habitat similar to natural spawning conditions. This theory is supported by Graham (1984). This theory does not however explain the relatively dispersed nature of the lower Nelson River lake sturgeon as indicated by their many capture locations (Swanson and Kansas 1987).

It is not likely that the sturgeon tagged 48.042 Mhz is dead as localized movements within area 5 have been noted. Similarily movements in area 4 have been observed by one sturgeon tagged with a small 90 day transmitter (Swanson and Kansas 1987). These data do not appear to fit the overall movement pattern and the movements of these two sturgeon may indicate that there is a sedentary portion of the Nelson River lake sturgeon stocks.

Utilization of small reservoirs like Long Spruce Reservoir by sturgeon seems unlikely. While a few sturgeon were sampled in the Long

Spruce Reservoir (Swanson 1986) no recruitment was observed in two years of experimental netting there (Swanson 1986; Swanson and Kansas 1987). Morever, the extensive movements undertaken by many lower Nelson River sturgeon below Long Spruce Generating Station indicates that reservoirs similar to Long Spruce Reservoir (i.e. Limestone and Conawapa forebays) may not be large enough to harbor sturgeon populations. Transferred sturgeon data supports this. Furthermore, reduced populations levels in reservoirs and the fact that sturgeon spawn as little as once every seven years makes the possibility of self-propogating sturgeon populations in these reservoirs remote. The lone exception to this appears to be the Gillam Island Forebay where lake sturgeon utilize Angling Lake extensively.

SUMMARY

In summary, sturgeon in the Lower Nelson River and the Angling River utilize the river extensively in the summer months as a navigational medium and for foraging. Overwintering occurs in at least three discrete areas (Areas 1-3; Figure 12). Spawning migrations have not been defined as yet due to catching all 9 sturgeon after spawning occurred and the fact that sturgeon seldom if ever repeat spawning in consecutive years (Sunde 1961, Priegel and Wirth 1977).

The maintenance of self propogating lake sturgeon stocks in Limestone and Conawapa forebays seems unlikely. Sturgeon movements are often extensive extending over 100 km in a couple of weeks. It does appear however that sturgeon may remain in the Angling River Watershed - Gillam Island Forebay system although the contribution of Angling Lake to Nelson River lake sturgeon stocks is not understood at present.

RECOMMENDATIONS

1. The commercial lake sturgeon fishery should be closed and remain that way.
2. Current radio telemetry experiments should be continued and expanded to include Angling Lake lake sturgeon.
3. An inventory of the Angling Lake lake stugeon resources should be carried out to assess the contribution of this system to the overall Lower Nelson River lake sturgeon stocks.

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ANGLING LAKE

INTRODUCTION

An inventory of the fishery resources of Angling Lake was conducted by the Manitoba Department of Natural Resources Fisheries Branch from July 2-10, 1987. The objectives of the inventory were to provide baseline data, to assess the sport fish potential of the lake and to develop a use strategy for the fishery resource.

Angling Lake supports a small sport fishery with winter and summer components. There is presently no road link to the lake and access is gained via air or by snowmobile in winter. The only permanent structure present is a small trapper's cabin on the west end of the lake; while a local outfitter's tent camp operated historically at the east end of the lake. Additionally one native user annually sets nets in the early winter for domestic purposes. There is presently no commercial fishery, however a commercial fishery for (*Acipenser fulvescens*) lake sturgeon was reportedly operated on Angling Lake in the 1930's (John Hatley, Silver Goose Lodge, pers. comm.).

STUDY AREA

Angling Lake is located approximately fifteen km ESE of the Limestone Generating Station and 754 km NNE of Winnipeg at 56°27'30" (N) and 93°53'30" (W), (Figure 1). It is a small mid-stream basin of the Angling River which is a tributary of the lower Nelson River. The study area lies just east of the Precambrian Shield/Hudson Bay Lowlands transition zone. This is an area characterized by recent non-glacial deposits consisting of layers of clay, silt and sand covered historically by seasonally submerged organic deposits (Weir 1983). The climate is humid subarctic featuring cool, short summers and long, cold winters with mean annual precipitation totalling 358 mm (Penner et al. 1975). The study area lies within the zone of discontinuous permafrost with thickness varying from 0.45 m to 1.8 m (Penner et al. 1975).

The natural vegetation of the area is classified as northern transition featuring mostly poorly drained coniferous forest characterized by black spruce (*Picea mariana*), eastern larch (*Larix laricina*), sedges (*Carex spp.*) and lichens (Didiuk 1975).

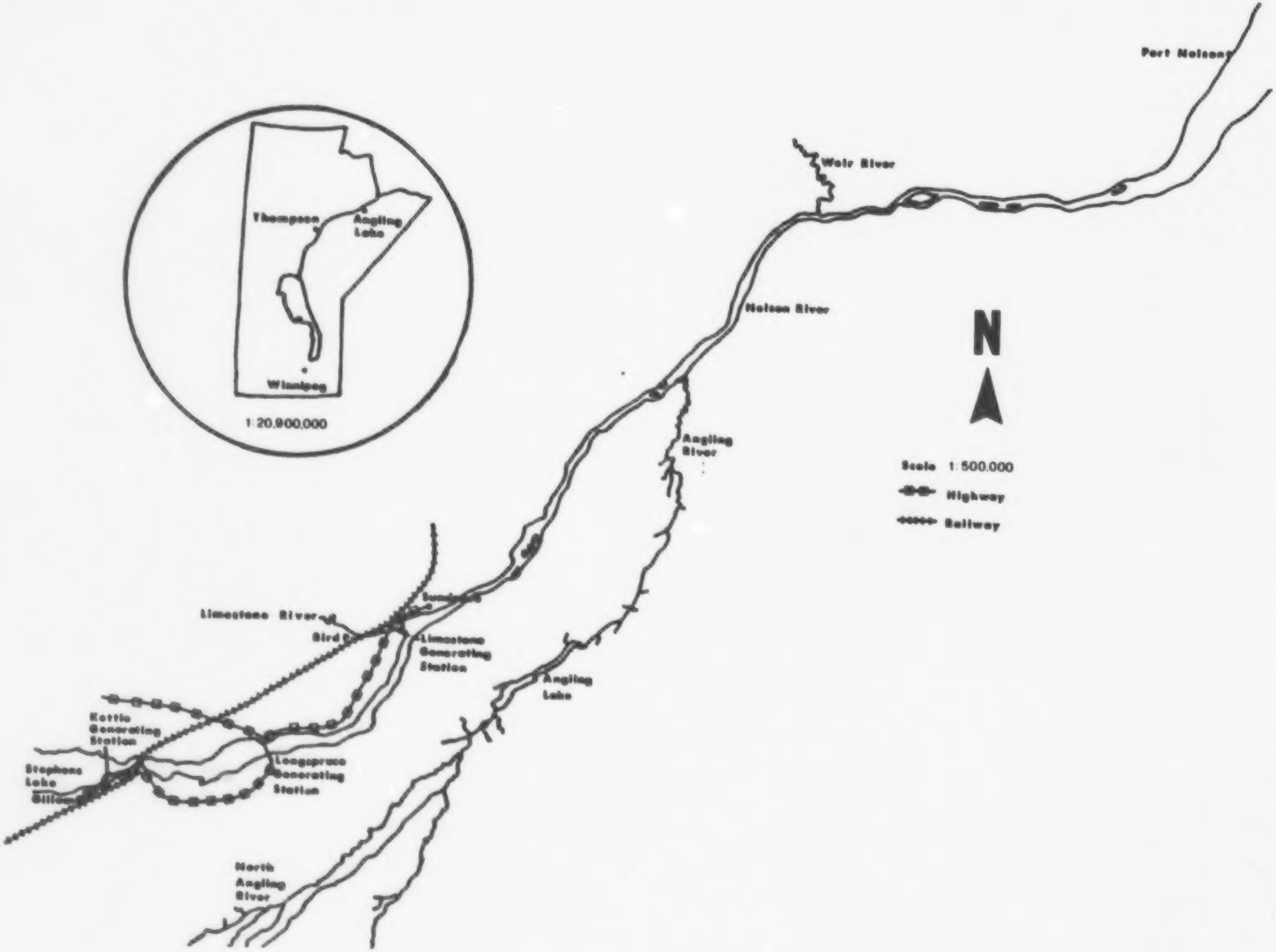
Port Nelson
Weir River
Nelson River
N
Scale 1:500,000
Highway
Railway
Angling River
Limestone River
Bird
Limestone Generating Station
Angling Lake
Kettle Generating Station
Stephens Lake
Gillam
Longspruce Generating Station
North Angling River
Thompson
Angling Lake
Winnipeg
1:20,900,000

Figure 1. Geographic location of Angling Lake.

METHODS

Physical Parameters

Angling Lake was depth-sounded using a Si-Tex model #HE-356 depth sounder with a range of 0 to 183 meters. Sounding transects were drawn in the field on a 1:50,000 scale map of the study area. Sounding transects were then used to develop a complete bathymetric map. Lake area, volume, mean depth and shoreline development index were computed as per Wetzel (1975). Edaphic parameters were not collected from Angling Lake therefore maximum sustainable yield (MSY) could not be computed using known morpho-edaphic index (MEI) values as per Ryder (1965). Other methods were utilized and are discussed later.

Fish Species

Forage fish were collected from representative areas of the lake using a 1.0 m by 5.0 m beach seine of 3.0 mm mesh. Twenty meters of beach were seined giving a sample coverage of approximately 100 m^2 of lake surface area at each location. Fish captured by seine were preserved in 5% formalin and stored for subsequent identification, enumeration and volumetric measurement.

Larger fish fauna of Angling Lake were sampled using standard gangs of gill nets. Standard gangs were composed of six panels, each with a length of 22.9 m and a depth of 1.8 m. Mesh sizes used were: 3.8 cm (1.5 in.), 5.1 cm (2 in.), 7.6 cm (3 in.), 9.5 cm (3.75 in.), 10.8 cm (4.25 in.) and 12.7 cm (5 in.) stretch measure, in that order. Standard gangs were set overnight for approximately twenty one hours and were rotated around the lake in an attempt to sample all available habitat types. Additionally a 30 m by 3 m deep 22.86 cm (9 in.) mesh net was set to test for the presence of lake sturgeon in Angling Lake.

All fish captured were sampled for fork length and round weight and recorded by species. Total length was also recorded for lake sturgeon. For age determination cleithra were removed from northern pike (*Esox lucius*) and otoliths were collected from lake whitefish (*Coregonus clupeaformis*) and walleye (*Stizostedion vitreum*). Otoliths were removed for age determination from a portion of the yellow perch (*Perca flavescens*) sample to assess growth. Pectoral fin spines were removed for aging purposes from all but four of the lake sturgeon. These four fish were held and later transferred to Long Spruce Reservoir (See part 4). Ageing structures were analyzed by Fisheries Branch staff in Winnipeg. As target species; northern pike, lake whitefish and walleye were also examined for sex and state of maturity.

Calculations

For northern pike, lake whitefish and walleye growth was calculated from the equation formulated by von Bertalanffy (1938):

$$L_t = L_\infty (1-e^{-k(t-t_o)}),$$

where L_t = length(mm) at age t(years)

L_∞ = asymptotic length(mm)

e = a constant equal to the base of the natural log

k = rate of decrease in length increments

t_o = hypothetical age at which the fish length was zero.

Exponential growth curves were also developed for the three target species, A regression analysis of Log_e length versus Log_e age was required to compare growth of fish in Angling Lake with other northern lakes. Instantaneous rate of mortality (Z) was calculated using regression analysis of the descending limb of the catch curve. From Z, the annual total mortality rate (A) and its complement, the annual survival rate (S) were determined as per Ricker (1975). Mean age of sexual maturity was calculated for female fish according to Abrasov (1967).

RESULTS

Physical Parameters

Morphometric data for Angling Lake are presented in Table 1. A bathymetric map of the lake can be found in Figure 2. Angling Lake is shallow with a relatively undeveloped shoreline typified by few bays or islands.

Fish Species

Seine hauls were conducted in four locations as shown in Figure 3. A total of seven species of forage fish were collected from the seine hauls. Table 2 shows complete results of these collections. Only two of the species encountered would be classified as true forage species, with adults not attaining lengths of over 150 mm.

Twelve standard gangs were set in Angling Lake (Figure 3). Five hundred and one fish representing seven species and totalling 660 kg were caught in standard gangs as shown in Table 3. Age-specific mean lengths and weights were computed for the three target species and may be found in Table 4. In our sample, walleyes showed a much wider range of ages than the other two species. Appendices 10 and 11 present the results of gill net catches by individual gang.

Three overnight sets of the 22.9 cm mesh gill net were made to test for the presence of lake sturgeon (Figure 3). In total twenty four sturgeon were caught in standard gang sets and the larger meshed gill net combined. Catch results for the sturgeon gillnet sets and for all

Table 1. Morphometric data for Angling Lake.

Parameter	Value
Surface area (ha)	689.6
Maximum depth (m)	9.5
Mean depth (m)	2.64
Volume (cubic meters x 1,000,000)	18.213
Length of mainland shoreline (km)	30.5
Shoreline development index	3.28

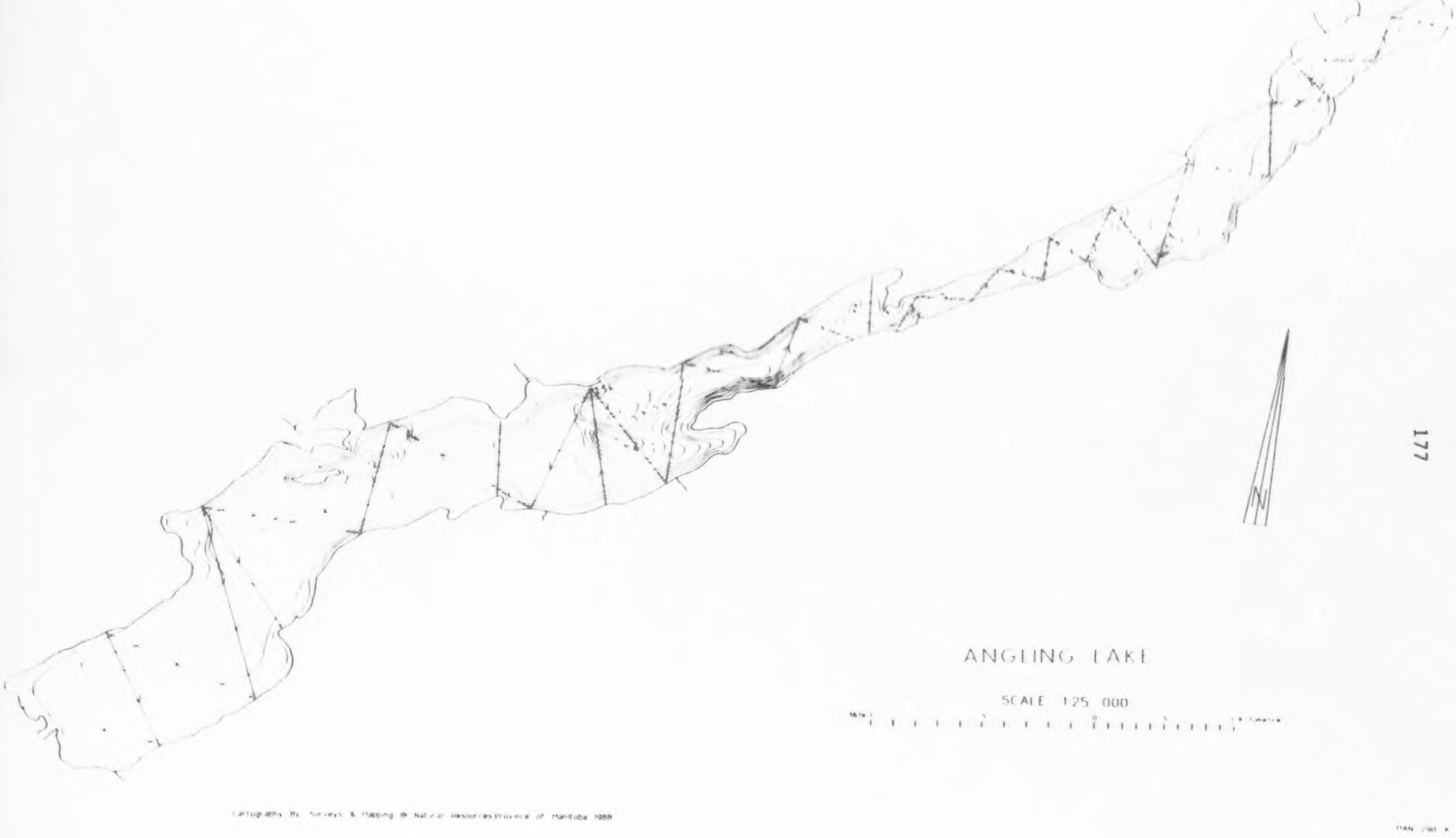
ANGLING LAKE
SCALE 1:25 000
Mile
0
Kilometre
N
Cartography By Surveys & Mapping Br. Natural Resources/Province of Manitoba 1988

Figure 2. Bathymetric map of Angling Lake (depth in meters).

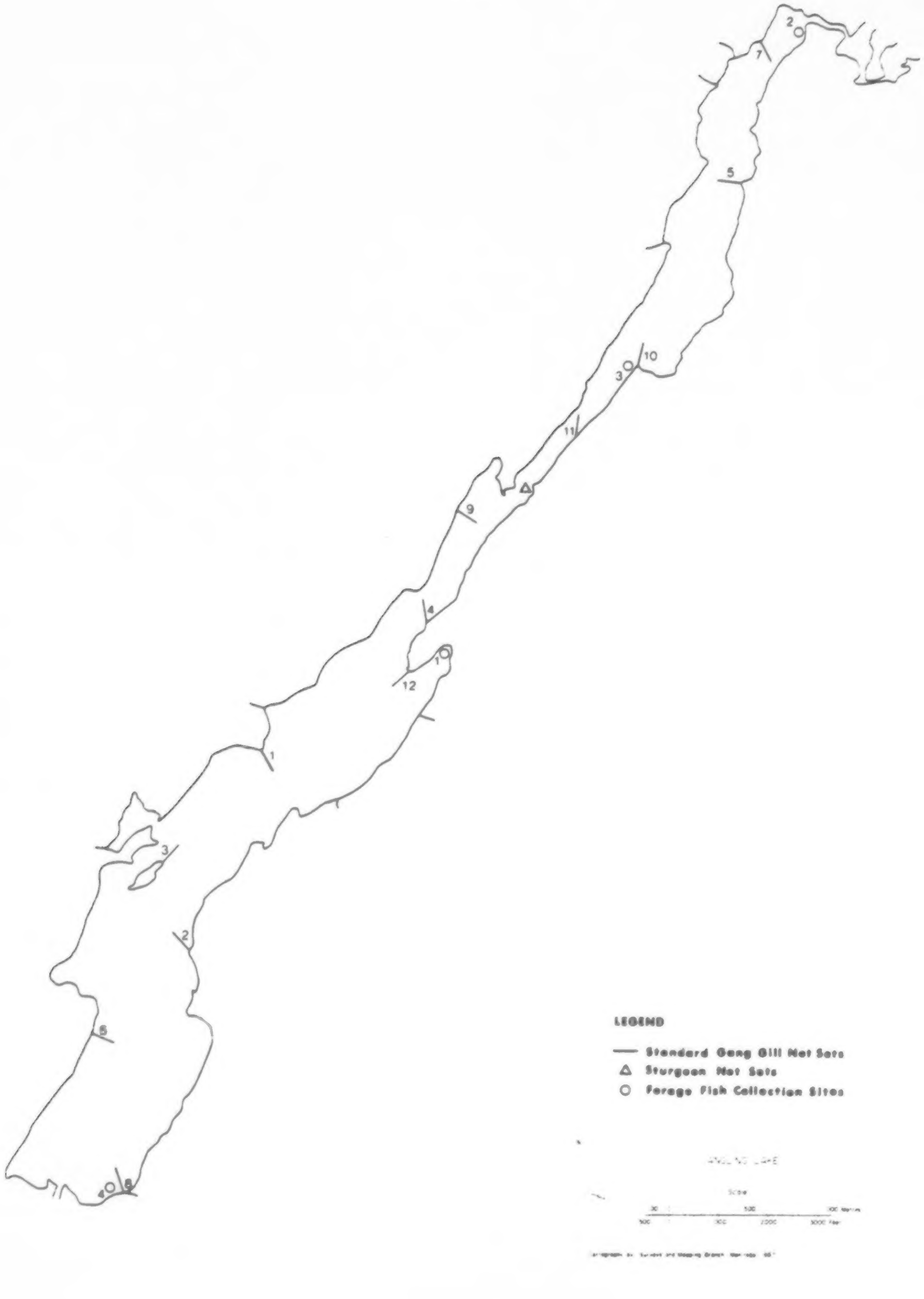
2
7
5
10
3
11
9
4
1
12
1
3
2
5
4
6
LEGEND
Standard Gang Gill Net Sets
Sturgeon Net Sets
Forage Fish Collection Sites
ANGLING LAKE
Scale

Figure 3: Location of fish collection sites in Angling Lake in 1987.

Table 2. Frequency and volume of forage fish species sampled in seine net hauls in Angling Lake in 1987.

Species	Frequency (#)					Volume (ml)				
	Site 1	Site 2	Site 3	Site 4	Total	Site 1	Site 2	Site 3	Site 4	Total
White Sucker (*Catostomus commersoni*)	110	1003	1579	648	3340	14.0	135.0	218.5	90.0	457.5
Log Perch (*Percina caprodes*)	6	1	4	37	48	5.0	1.0	0.5	74.0	80.5
Yellow Perch (*Perca flavescens*)		1	11	1329	1341		0.5	1.5	193.5	195.5
Walleye (*Stizostedion vitreum vitreum*)	1		6	32	39	0.5		1.5	8.0	10.0
Lake Cisco (*Coregonus artedii*)		1	1		2		0.5	0.5		1.0
Northern Pike (*Esox lucius*)	2				2	34.0				34.0
Slimy Sculpin (*Cottus cognatus*)	2				2	1.0				1.0
Total	121	1006	1601	2046	4774	54.5	137.0	222.5	365.5	779.5

Table 3. Total catch (frequency), weight (kg) and catch per unit effort (# or weight/standard gang/night) for all species sampled in Angling Lake in 1987.

Species	Frequency	CPUE	% Comp	Weight	CPUE	% Comp
Northern Pike (*Esox lucius*)	134	11.17	26.7	336.785	28.065	51.0
Lake Whitefish (*Coregonus clupeaformis*)	65	5.42	13.0	48.445	4.037	7.3
Walleye (*Stizostedion vitreum vitreum*)	91	7.58	18.2	71.220	5.935	10.8
Yellow Perch (*Perca flavescens*)	53	4.42	10.6	1.625	0.135	0.2
Lake Sturgeon (*Acipenser fulvescens*)	9	0.75	1.8	53.886	4.491	8.2
White Sucker (*Catostomus commersoni*)	129	10.75	25.7	146.150	12.179	22.2
Lake Cisco (*Coregonus artedii*)	20	1.67	4.0	1.750	0.146	0.3
Total	501	41.76	100	659.861	54.988	100

Table 4. Age-specific mean lengths and weights of northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

Age	Northern Pike No.	Freq.(%)	X length	X weight	Lake Whitefish No.	Freq.(%)	X length	X weight	Walleye No.	Freq.(%)	X length	X weight
1	1	0.75	294.00	160.00	0	0	0	0	0	0	0	0
2	9	6.77	340.00	272.22	0	0	0	0	0	0	0	0
3	11	8.27	420.91	580.00	5	7.69	256.80	210.00	4	4.40	185.50	62.50
4	11	8.27	483.82	856.36	11	16.92	295.18	344.55	11	12.09	227.00	114.55
5	14	10.53	571.79	1505.71	2	3.08	301.50	355.00	0	0	0	0
6	14	10.53	645.29	1997.14	16	24.62	355.25	714.38	3	3.30	298.00	263.33
7	18	13.53	672.50	2281.67	13	20.00	390.31	918.08	0	0	0	0
8	18	13.53	715.06	2898.89	3	4.62	407.33	966.67	3	3.30	382.00	573.33
9	9	6.77	785.78	4071.11	4	6.15	381.50	765.00	0	0	0	0
10	12	9.02	798.58	4401.67	5	7.69	425.60	1172.00	2	2.20	384.00	605.00
11	9	6.77	873.33	5213.33	0	0	0	0	12	13.19	370.92	536.67
12	3	2.26	930.67	5858.33	1	1.54	434.00	1040.00	3	3.30	409.33	730.00
13	2	1.50	867.00	4855.00	2	3.08	441.00	1160.00	3	3.30	421.00	756.67
14	0	0	0	0	1	1.54	406.00	950.00	18	19.78	422.00	802.78
15	2	1.50	950.00	6170.00	1	1.54	463.00	1480.00	4	4.40	420.50	767.50
16					0	0	0	0	3	3.30	454.67	923.33
17					0	0	0	0	1	1.10	414.00	750.00
18					0	0	0	0	3	3.30	458.67	1006.67
19					1	1.54	492.00	1920.00	1	1.10	513.00	1240.00
20									3	3.30	502.33	1276.67
21									12	13.19	530.42	1522.50
22									1	1.10	551.00	1680.00
23									0	0	0	0
24									3	3.30	501.00	1336.67
25									0	0	0	0
26									0	0	0	0
27									0	0	0	0
28									0	0	0	0
29									0	0	0	0
30									0	0	0	0
31									0	0	0	0
32									0	0	0	0
33									0	0	0	0
34									1	1.10	587.00	2000.00
Total	133	100.00	667.77	2937.25	65	100.00	388.42	922.74	91	100.00	422.75	892.01

sturgeon sampled are presented in Appendix 12.

Walford plots are summarized in Table 5 and presented in Figure 4. The L_∞ for lake whitefish is incorrect as 4.6% (n=3) of the whitefish caught were larger than 451.23 mm. This problem may be due to small sample sizes. Equations for von Bertalanffy and exponential growth curves are presented in Table 6 and illustrated in Figure 5. For all three target species the Brody curves demonstrated a higher correlation coefficient than did the exponential growth curves.

Length-weight regressions were calculated to determine isometric or allometric growth for each of the three target species as a whole. As shown in Table 7 all three species exhibited positive allometric growth with lake whitefish body form changing the most over its life (b = 3.254).

Appendix 13 summarizes the data for twenty three yellow perch from which aging structures were taken. For a subsample (n=10), of these twenty three perch, back-calculated lengths were derived for each age. Mean back-calculated lengths at ages one through seven, with 95% confidence limits for ages one to four are shown in Figure 6. Yellow perch grew from a mean length of about 60mm at 1+ years to 196mm for the lone 6+ perch.

Age-frequency distributions for the target species are presented in Figure 7. The histograms for northern pike and lake whitefish show good representation of all age classes. The walleye histogram is characterized by four spikes which may represent strong year classes. Regression estimates of mortality for northern pike, lake whitefish and walleye are presented in Table 8. For all three species

Table 5. Walford and Brody plot equations for northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

Walford Equations

Species	Equation	L_∞ (mm)	Correlation coefficient	F value (d.f.)*	Ages used to calculate regression
Northern Pike	$Y=113.828+0.895X$	1081.20	0.982	277.52 (1,10)	1-13
Lake Whitefish	$Y= 98.821+0.781X$	451.23	0.878	16.78 (1,5)	3-10
Walleye	$Y= 67.390+0.886X$	590.42	0.851	45.64 (1,9)	11-22

*All F values significant at P=0.05

Brody Equations

Species	Equation	t_0 (years)	Correlation coefficient	F value (d.f.)*	Ages used to calculate regression
Northern Pike	$\log(1081.20-L)=6.877-0.131X$	-0.832	-0.976	224.80 (1,11)	1-13
Lake Whitefish	$\log(451.23-L)=6.139-0.266X$	0.101	-0.934	41.32 (1,6)	3-10
Walleye	$\log(590.42-L)=6.780-0.121X$	3.286	-0.897	45.64 (1,11)	10-22

*All F values significant at P=0.05

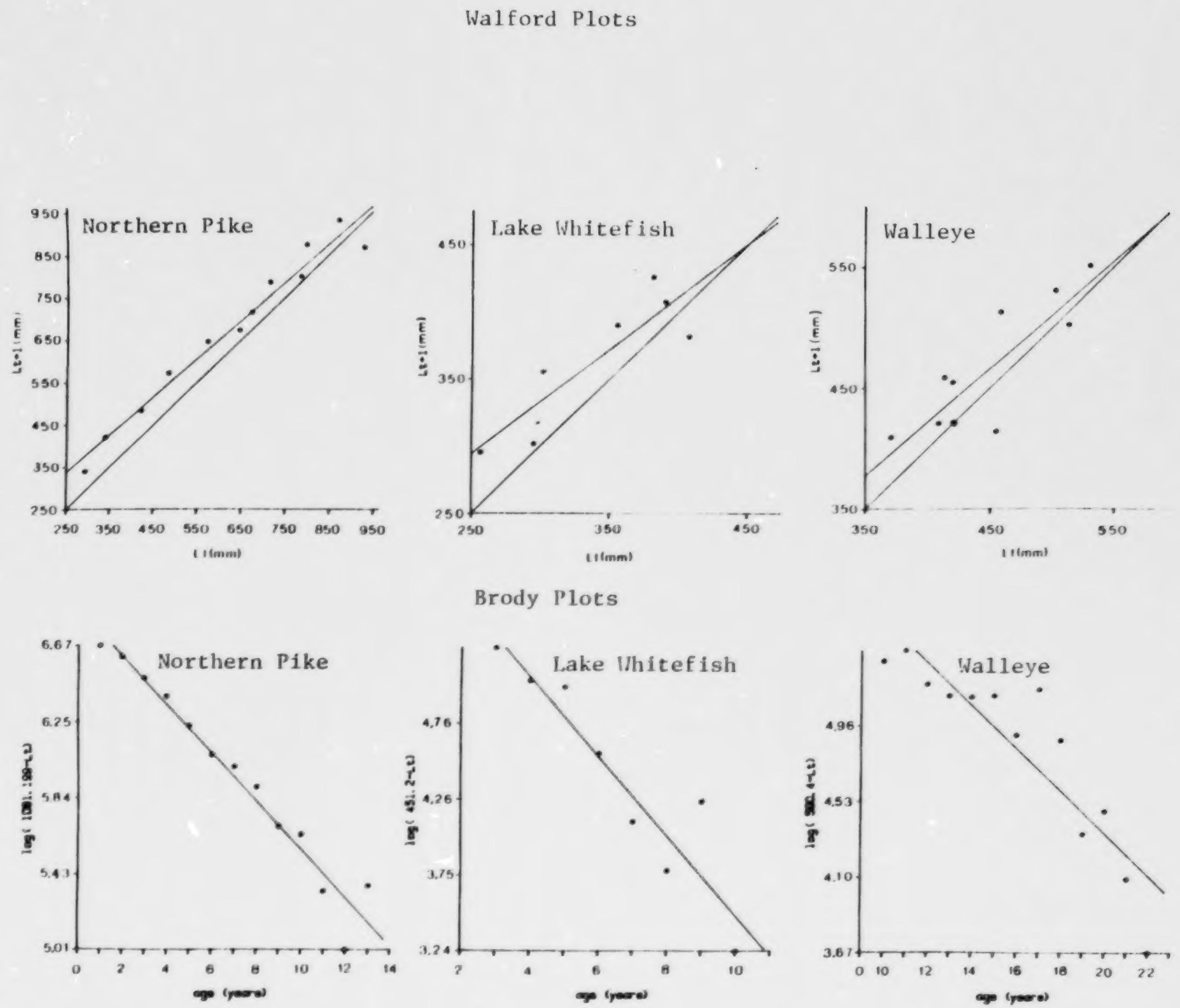

Figure 4: Walford and Brody plot equations for northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

Table 6. Von Bertalanffy and Exponential growth curves for northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

Von Bertalanffy

Species	Equation
Northern Pike	$L = 1081.20\ (1-e^{-0.131(t+0.83)})$
Lake Whitefish	$L = 451.23\ (1-e^{-0.266(t-0.10)})$
Walleye	$L = 590.42\ (1-e^{-0.121(t-3.29)})$

Exponential

Species	Equation	Correlation coefficient	F value (d.f.)*
Northern Pike	$\log = 5.817+0.083X$	0.943	97.08 (1,12)
Lake Whitefish	$\log = 5.602+0.036X$	0.889	41.40 (1,11)
Walleye	$\log = 5.504+0.034X$	0.870	52.81 (1,17)

*All F values significant at P=0.05

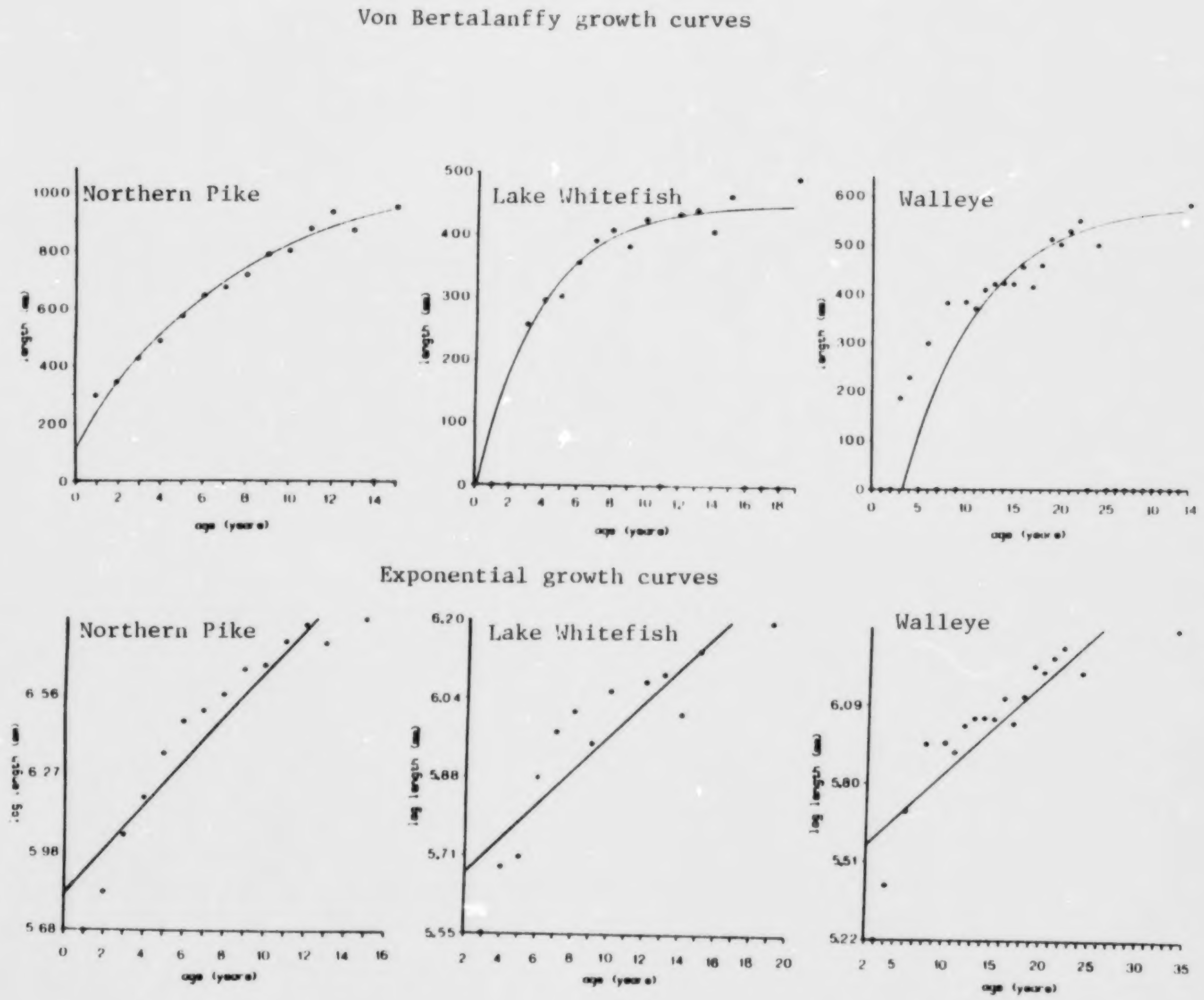

Figure 5: Von Bertalanffy and Exponential growth curves for northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

Table 7. Length-weight regressions for northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

Species	Length-weight equation	Correlation coefficient	F value*	d.f.
Northern Pike	$\log_e$ weight = $-12.508+3.111 \log_e$ length	0.998	3586.33	1,12
Lake Whitefish	$\log_e$ weight = $-12.672+3.254 \log_e$ length	0.994	852.55	1,11
Walleye	$\log_e$ weight = $-11.590+3.016 \log_e$ length	0.999	8482.6	1,17

*All F values significant at $P=0.05$

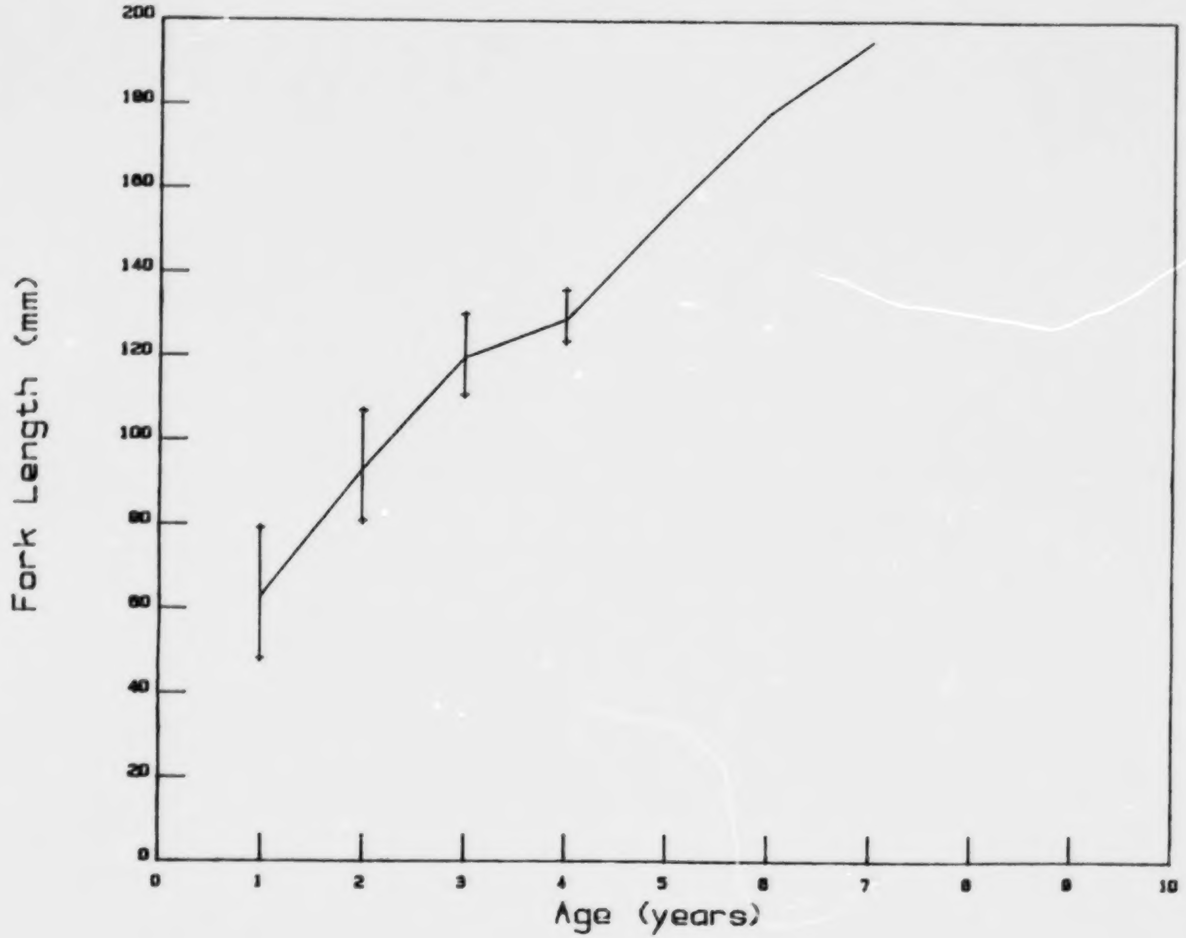

Figure 6: Mean back-calculated lengths with 95% confidence limits for ages one to four of ten yellow perch sampled in Angling Lake in 1987.

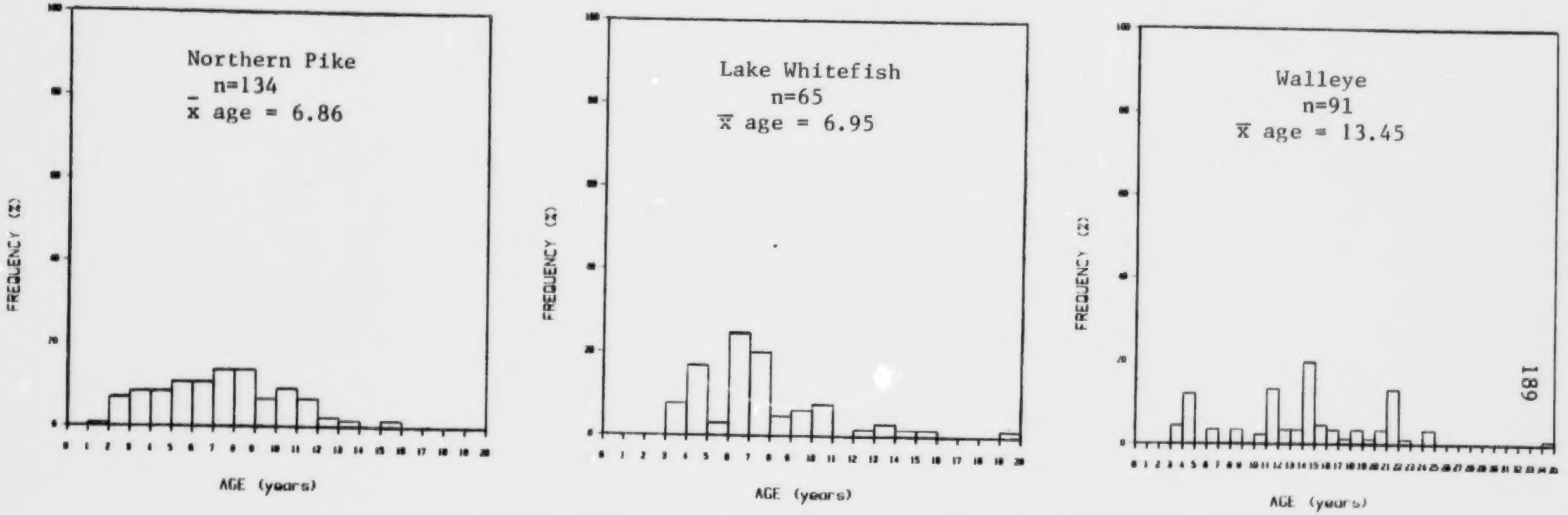

Figure 7: Age-frequency distributions for northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

Table 8. Regression estimates of northern pike, lake whitefish and walleye mortality rates for fish sampled in Angling Lake in 1987.

Species	Z	A	S	Ages used to calculate Z	Correlation Coefficient	F value*	d.f.
Northern Pike	0.329	0.280	0.720	(8–15)	−0.894	23.97	1,6
Lake Whitefish	0.186	0.170	0.830	(7–19)	−0.752	14.33	1,11
Walleye	0.086	0.082	0.918	(15–34)	−0.661	13.95	1,18

*All F values significant at P=0.05
Z = Instantaneous mortality rate
A = Annual mortality rate
S = Annual survival rate

mortality rates are shown to be low with walleyes exhibiting an annual mortality rate of only 8.2%.

Sex and maturity data for northern pike, lake whitefish and walleye are presented in Table 9. Both northern pike and walleye show a much higher percentage of females than males. Mean age of sexual maturity could not be calculated for lake whitefish due to insufficient data for a significant regression.

As previously mentioned, due to the absence of total dissolved solids (TDS) data, an MEI value was not obtained. In order to attempt to predict MSY for Angling Lake several alternative approaches were used. Alkalinity was estimated by extrapolating Ontario alkalinity isolines and TDS was estimated from a regression of alkalinity versus TDS (Ryder 1964). Thus, a TDS value of 112.8 was generated for Angling Lake. Using a modified metric version of Ryder's original equation (Ryder 1965), as per Ryder et al. (1974), the MEI value for Angling Lake was calculated at 42.7 which gave an initial estimated MSY of 6.314 kg/ha/yr. Given the questionable nature of this TDS value, an alternate method of calculating MSY incorporating only mean annual temperature was used, where: $\log_{10} \mathrm{MSY} = 0.061\ \mathrm{TEMP} + 0.043$ (Schlesinger 1982). Using a thirty year (1951-1980) mean annual temperature of -5.4°C for Bird, Manitoba (Environment Canada 1982), the estimate for MSY was determined to be 0.517 kg/ha/yr.

A third method, also described by Schlesinger (1982), incorporates mean annual temperature and MEI in the following equation: $\log_{10} \mathrm{MSY} = 0.050\ \mathrm{TEMP} + 0.280 \log_{10} \mathrm{MEI} + 0.236$. The MEI value used in this equation is the one previously calculated. Using this method MSY was estimated at 2.64 kg/ha/yr. This value falls between the

Table 9. Sex and maturity data for northern pike, lake whitefish and walleye sampled in Angling Lake in 1987.

	Northern Pike	Lake Whitefish	Walleye
Sex ratio (males to females)	1 : 2.80	1 : 0.91	1 : 6.00
Percent mature males	82.9	52.9	69.2
Percent mature females	83.9	74.2	65.4
Mature sex ratio (m to f)	1 : 2.83	1 : 1.28	1 : 5.67
Mean age at maturity	3.43	----	9.30
Age at 100% maturity	7	8	22

other two and therefore may be seen as a median estimate of MSY. Furthermore MSY isolines for Manitoba, developed by the provincial sport fisheries section, estimate Angling Lake yield to be in the order of 2.75 kg/ha/yr. (B. Corbett, Provincial Fisheries Branch, pers. comm.). Because it approaches the provincial constant, an MSY value of 2.64 kg/ha/yr. will be used in subsequent discussion.

DISCUSSION

Angling Lake is a relatively small shallow lake with a rocky but weedy shoreline. Since 37.5% of the surface area of the lake has an underlying depth of less than 2.0m, the zone of light penetration is extensive. The estimated TDS value is large and taking into account the lake's northerly location fairly good productivity may be expected. Although the diversity of true forage species is low the abundance of young of the year (Y.O.Y.) white sucker (Catostomus commersoni) and yellow perch appears high. The abundance of Y.O.Y. yellow perch in one location indicates good spawning success in that part of the lake. Young of the year yellow perch of the size encountered in Angling Lake would be expected to move only locally and primarily by wind drift indicating a spawning area close to the sample site (B. Wong, Fisheries and Oceans, pers. comm.). Young of the year yellow perch have been identified as a major food source of walleye (Clady and Nielsen 1978), and among the identifiable fish remains yellow perch was the most common species found in the stomachs of Angling Lake northern pike.

Angling Lake target species showed growth rates generally comparable with those from other studies. For representative purposes exponential growth rates of northern pike, lake whitefish and walleye from Angling Lake were compared with twenty lakes from Lysack's (1982) study of relatively unexploited northern lakes and with seventeen lakes from the east side of Lake Winnipeg (Hagenson 1984). Exponential growth curves were used, however Angling Lake data had to be converted to $\log_e$ length-$\log_e$ age form for direct comparison. As shown in

Table 10 Angling Lake northern pike and lake whitefish showed growth rates below the mean and median growth rates for thirty one northern pike lakes and nineteen lake whitefish lakes. Angling Lake walleyes showed a growth rate above the mean and median values for the thirty lakes with walleye present. In general terms then, walleye in Angling Lake show better relative growth than did northern pike and lake whitefish.

Angling Lake yellow perch exhibited a greater mean length at each subsequent age and therefore do not appear to be stunted. As shown in Figure 6 growth of yellow perch appears to tail off between ages three and four and then rebounds beyond age four. Only two fish older than four were aged however and growth rate based on two fish may not be representative of true growth rates. Four lakes sampled in the Duck Mountains area of Manitoba showed good growth of yellow perch for their first four years at which time the populations appeared to become stunted (B. Olynyk, Provincial Fisheries Branch, pers. comm.). These lakes were all part of closed systems and featured no predator species with yellow perch being the dominant carnivore. While the existence of an open system combined with the presence of predators and apparent good growth rate support the conclusion that the yellow perch of Angling Lake are not stunted no large yellow perch were sampled. This may indicate high mortality. When attempting to analyze this sample it must be noted that the sample size is very small and thus any inferences must be made with caution.

Angling Lake walleye were older fish while northern pike and lake whitefish were comparable to other northern Manitoba lakes. Age-frequency distributions yielded mean ages of 6.86 for northern pike,

Table 10. Comparison of exponential growth rates of northern pike, lake whitefish and walleye in Angling Lake, 20 lakes in northern Manitoba and 17 lakes on the east side of Lake Winnipeg.

Rank	Northern Pike/Lake	Lake Whitefish/Lake	Walleye/Lake
1	0.816 Max *	0.587 James *	0.800 Cuddle *
2	0.710 Semple *	0.583 X *	0.711 Fairy Rock *
3	0.709 Cuddle *	0.528 Numakoos *	0.698 X *
4	0.693 Mackerracher II *	0.491 Ankle *	0.628 Aswapiswanan *
5	0.674 Bearhead *	0.473 Enatik *	0.604 Mackerracher II *
6	0.672 MacBride *	0.452 Cuddle *	0.546 Denison *
7	0.657 Denison *	0.432 Semple *	0.521 Mackerracher I *
8	0.650 Wass *	0.423 Fairy Rock *	0.486 Enatik *
9	0.646 Pine *	0.373 Mackerracher I *	0.480 Vickers +
10	0.618 Enatik *	0.352 Willow *	0.465 Max *
11	0.616 Weaver +	0.341 Denison *	0.461 Angling
12	0.602 X *	0.334 Angling	0.452 Ankle *
13	0.587 Ankle *	0.312 Bearhead *	0.443 Wass *
14	0.583 Horseshoe +	0.301 Mackerracher II *	0.391 Eardley +
15	0.583 Numakoos *	0.283 Max *	0.383 Dogskin +
16	0.579 McPherson *	0.253 McPherson *	0.379 Sasaginnigak +
17	0.553 Mackerracher I*	0.252 Pine *	0.377 Bearhead *
18	0.531 Fairy Rock *	0.250 Whitefish *	0.362 Willow *
19	0.505 Sasaginnigak +	0.124 Aswapiswanan *	0.335 Ewart +
20	0.494 Willow *		0.329 Aikens +
21	0.481 Viking +		0.324 Harrop +
22	0.480 Angling		0.305 Carr-Harris +
23	0.469 Obukowin +		0.299 Family +
24	0.450 James *		0.258 Viking +
25	0.443 Wrong +		0.226 Charron +
26	0.438 Dogskin +		0.218 Weaver +
27	0.399 Harrop +		0.208 Morfee +
28	0.397 Eardley +		0.201 Obukowin +
29	0.380 Family +		0.193 Lynx +
30	0.379 Whitefish *		0.178 Wrong +
31	0.364 Charron +		
Mean	0.553	0.376	0.409

* from Lysack (1982)
+ from Hagenson (1984).

6.95 for lake whitefish and 13.45 for walleye. Lysack's (1982) pulse fishing study produced comparable mean ages for northern pike and lake whitefish. Hagenson (1984) found mean ages of 5.8 and 6.5 years for Sasaginnigak and Charron Lake northern pike respectively. Lysack (1982) found mean age of walleyes to range from 4.57 to 8.97 from thirteen lakes. Hagenson (1984) found mean ages of 8.9 and 10.0 years for Sasaginnigak and Charron lake walleye respectively. Swanson (1986), and Swanson and Kansas (1987) found mean ages of Longspruce Reservoir walleye to be 3.99 and 4.10 in 1985 and 1986 respectively. This illustrates the relative antiquity of the Angling Lake walleye sample.

In general, mortality rates seemed low and conversely survival rates high for all three target species in Angling Lake when compared with lakes from the pulse fishing program (Lysack 1982). The annual mortality rate for northern pike was lower than all but two of seventeen lakes from which data were available. Lake whitefish annual mortality rate was lower than all but one of fifteen lakes from which data were available and walleye annual mortality rate was lower than all fourteen lakes from which data were available. Present low fishing pressure on Angling Lake reduces the impact of fishing mortality and hence total mortality is comprised primarily of natural mortality. Additionally the influence of strong year classes and the presence of one or two very old fish, particularly in the case of walleye influences estimates of the survival rate. This is a problem for all parameters estimated in cross sectional sampling programs and they therefore only serve as rough estimates of the true value subject to very wide confidence intervals.

Sex ratios of mature fish showed more females present than males for all three species. Given walleye spawning behaviour whereby one or two females are attended to by two to six males (Scott and Crossman 1979), a mature sex ratio of 5.57 females for every male appears large. Hagenson (1984) found mature walleye sex ratios of one male to 3.35 females and one male to 4.72 females for Sasaginnigak and Charron lakes which indicates that the sex ratio of Angling Lake walleye may not be abnormally high. The sex ratio of Angling Lake mature pike was also comparable to those found in Sasaginnigak and Charron lakes (Hagenson 1984).

Mean ages of sexual maturity for Angling Lake northern pike and walleye were found to be comparable with those of Sasaginnigak and Charron lakes. Mean age of maturity for northern pike was determined to be 3.43 years. Scott and Crossman (1979) give 6.0 as the age of maturity of northern female northern pike. Hagenson (1984) found mean ages of maturity to be 3.8 and 3.2 for Sasaginnigak and Charron lakes northern pike, which are comparable to the Angling Lake value. Mean age of sexual maturity for walleyes may be somewhat inflated due to the presence of alternate year spawners that were identified as immature. By July in many cases the residual eggs in walleye have been resorbed making identification of mature alternate year spawners difficult (Olynyk 1980). For female walleyes Scott and Crossman (1979) cite the age of maturity to be 3-6 years. In Angling Lake mean age of sexual maturity was found to be 9.30, very high when compared to the above, but more comparable with the 8.6 and 7.0 which Hagenson (1984) found for Sasaginnigak and Charron lakes respectively.

Management Implications

The calculated MSY value of 2.64 $kg.ha^{-1}.yr^{-1}$ is considered to be a liberal estimate of the actual MSY which would have been calculated had TDS been measured in Angling Lake. Recent measures of conductivity in the Angling River proper revealed specific conductivities of $\sim$100 $\mu mhos.cm^{-1}$. TDS in $mg.l^{-1}$ was observed to vary from conductivity, in $\mu mhos.cm^{-1}$, by factors of 0.43-1.18 in northern Manitoba lakes (Lysack 1982). In fact the numerical TDS value was less than the conductivity level in 13 of the 14 lakes for which data were available. This may indicate that the actual TDS value in Angling Lake is less than the 112.8 $mg.l^{-1}$ used. Consequently the estimated MSY could be as low as 2.0 $kg.ha.^{-1}.yr^{-1}$. Moreover, the fact that Angling Lake is really just a "wide spot in the river" means that Angling Lake conductivities are probably similar to those observed in the river proper. The calculated value of 2.64 $kg.ha^{-1}.yr^{-1}$ will however be used in subsequent discussion and conclusions will be made keeping in mind that the more liberal, calculated MSY value may serve to underestimate the level of exploitation.

Sport and domestic fisheries presently exist on Angling Lake. Creel census data are unavailable, therefore no precise figures can be placed on the level of effort and harvest. Estimates of the current level of sport harvest were obtained from Bob Monkman (the Gillam Brook Trout Association) and domestic harvest estimates were supplied by the local Natural Resources Officer. An estimated 200 kg of northern pike and 22.7 kg of walleye are currently harvested annually by the sport fishery. Annual domestic harvest if placed at 230 kg (P. Roberts, N.R.O.

Sundance, pers. comm.). Based on allowable domestic mesh size being no smaller than 10.8 cm, and experimental gill net catches (refer to Appendix 14), northern pike and walleye could be expected to account for 32.6% and 5.5% of the weight respectively of the domestic catch. Therefore of a given 230 kg, 74.0 kg of northern pike and 12.5 kg of walleye may be expected to be harvested annually. An additional source of harvest on Angling Lake appears to be illegal netting. In fact a large mesh gillnet (23 cm or 9") was discovered in the fall of 1987 with rotten fish present. A recent trip in the summer of 1988 to Angling Lake also revealed the presence of an illegal gillnet with large walleye, pike and lake sturgeon in it.

The estimated present level of total legal harvest is 24.9% of MSY. Total harvest includes species caught by domestic fishermen such as lake whitefish and lake sturgeon which are not a major component of the sport fishery. The combined harvest of the two sport species (northern pike and walleye) by both user groups (sport and domestic) is 17.2% of MSY. This can be further broken down showing that northern pike is harvested at 15.3% of MSY and walleye at 1.9% of MSY.

SPOF Working Group (1982) has determined that for a self-sustainable moderate quality sport fishery no more than 57% of the MSY should be harvested. Furthermore they subdivided the potential yield into individual species yields of 32% for walleye and 25% for northern pike sport fisheries. Hagenson and O'Connor (1978) working on God's Lake determined that no more than 15% of the MSY should be harvested to ensure sustained high quality sport fishing. This figure has since been used as a management tool for determining the guest capacity of fishing lodges at several northern Manitoba lakes (B. Corbett, Provincial Fisheries Branch, pers. comm.).

Presently the legal level of harvest of sport species is at least slightly above the recommended level for a sustained high quality sport fishery. The present annual take of northern pike constitutes 88.8% of the harvest of both sport species. Angling Lake northern pike exhibit fast growth, a fairly low age of sexual maturity and a good representation of all age classes. The combination of these factors combined with the relative abundance of northern pike in the sample (26.7% by number and 51.0% by weight) suggest that the present level of harvest of northern pike in Angling Lake is suitable. Noticably absent from our sample were any northern pike greater than 6.5 kg, however reports from anglers cite many over 9.0 kg still present in the lake (B. Monkman, Gillam Brook Trout Association, pers. comm.). Perhaps the illegal gillnetting present in Angling Lake has contributed to a reduction in large northern pike.

Walleyes are presently being harvested at 1.9% of MSY, a level which consistutes only 11.2% of the current harvest of sport species. Characteristics of relatively unexploited percid populations include slow growth rate and an elevated age of first sexual maturity (Kelso and Bagenal 1977, Spangler et al. 1977). Angling Lake walleye exhibit a relatively high age of first sexual maturity however the growth rate appears to be good. High mean age of the sample and low rate of mortality, other possible indicators of low exploitation rate may be influenced by the strength of some age classes. Variations in year-class strength that are usually linked with exploited populations (Spangler et al. 1977), have also been reported for unexploited (Kelso and Bagenal 1977) and lightly fished walleye populations (Moenig 1975; Mosindy et al. 1987). The high mean age of the Angling Lake sample is particularly influenced by the strength of the 1966 year class, (21+ years old), a cohort that Mosindy et al. (1987) also found to be particularly strong in Savanne Lake, Ontario.

The apparent contradictory characteristics of good growth rate versus elevated age of first sexual maturity and high mean age of the sample may be explained by the fact that walleye are currently being harvested at only 0.051 kg/ha/yr. Although the present level of sport harvest is low (particularly walleye) it may be that higher levels of effort in previous years resulted in a greater harvest of sport species. Although no creel census' data are available, during the 1970's and early 1980's an outfitter regularly flew a few guests into the lake and occassional pressure from other fly-in anglers was also incurred (B. Monkman, Gillam Brook Trout Association, pers. comm.). It therefore is possible that the good growth rates exhibited by the walleye and to a lesser extent northern pike are in responss to prior levels of exploitation. Decreased success experienced by these anglers may have resulted in the reduced pressure presently placed upon Angling Lake. There are no creel census statistics to support this but the quality of sport fishing has reportedly improved in the last few years (B. Monkman, Gillam Brook Trout Association, pers. comm.).

It has been suggested that a year-round or winter road be developed into Angling Lake. Among other uses the road would serve to open up an alternative fishery in order to deflect some of the fishing pressure away from the lower Nelson River tributaries. This proposal brings up several concerns, some of which will be addressed here.

The present level of total harvest of the two sport species is estimated at 17.2% of MSY, slightly above the recommended level for sustenance of a high quality sport fishery of 15% of MSY but well below 57% of MSY, a harvest level suitable for maintenance of a moderate quality sport fishery. Therefore, despite using a liberal estimate of MSY the harvest of sport fish will still only just maintain a high quality sport fishery. In fact harvest may be as high as 23% of MSY if an MSY of 2.0 $kg.ha^{-1}.yr^{-1}$ is used. Moreover, the sensitivity of managing a small boreal lake for quality sport fishing has been documented. Mosindy et al. (1987) working on a northern Ontario body of water of comparable size and character to Angling Lake found it took only 1.24 angler-hours/hectare to remove 43% and 50% of the estimated annual adult production of walleyes and northern pike respectively. This demonstrates the vulnerability of mature fish to angling in these populations and suggests that increased access may detriment the Angling Lake sport fishery.

It is difficult to predict how much additional fishing effort would be accrued by Angling Lake with the development of a year-round or seasonal road. In addition to the increase in angling effort, any road into the lake could also be expected to increase the domestic fishing pressure placed upon the lake. Given the terrain the development of a year-round road is unlikely. It is anticipated however, that even without a winter road the fishing effort on Angling Lake will increase.

Once the Limestone Generating Station has been completed (scheduled for winter 1989-90) the forebay will freeze and increased snowmobile access to the east side of the Nelson River will be afforded; thus fishing pressure could be expected to increase.

It also must be established for whom the alternate fishery is to be created. Increased access in the form of a road to Angling Lake may benefit some domestic fishermen and other permanent resident anglers. However short-term residents who are in the area only for the period of construction of the generating station may not have the same respect for the long-term environmental management of the area. If a road is opened up to Angling Lake in the near future the increase in angling pressure that can be expected to be placed upon the system by transient workers may be too much for the sport fish populations of the lake to withstand.

Finally, the presence of lake sturgeon in Angling Lake may represent a refugia of sorts for all or part of the lower Nelson River lake sturgeon's life history. Given the large movements demonstrated by lake sturgeon in the Nelson River (Swanson and Kansas 1987) and the relatively small forebays to be created by Limestone, Conawapa and Gillam Island Generating Station, Angling Lake may represent an opportunity to maintain Lower Nelson River lake sturgeon stocks. In this respect Angling Lake may be seen as sensitive fisheries habitat.

RECOMMENDATIONS

1. Given the sensitivity of Angling Lake to potential overexploitation of its fishery resources from increased effort by sport and domestic fishermen and the sensitivity of lake sturgeon in the area the development of a year-round or seasonal road is not recommended at this time.

2. If at any time in the future the development of a road into Angling Lake is considered, consultation with any frequent users of the lake and groups such as the Gillam Brook Trout Association, the Gillam Fur Council and the Fox Lake Band should be carried out to allow their concerns to be voiced. Additionally, accurate creel census information should be gathered to properly assess the level of effort and harvest prior to any development which increases access to the lake.

3. Regular enforcement patrols to Angling Lake during the winter and summer season should commence in 1988 and continue until after impoundment of the Limestone Generating Station. This will allow protection of the fisheries resource as well as an indication of increased effort as facilitated by forebay freezing near the Limestone Generating Station.

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MONITORING

INTRODUCTION

In response to concerns raised in the Limestone Generating Station Environmental Impact Study (McLaren Plansearch Inc./Intergroup Consultants Ltd. 1985) longterm monitoring of brook trout stocks within the Limestone Forebay and Limestone River was initiated. Monitoring studies included: 1) Floy tag recapture data, 2) juvenile brook trout stream utilization levels, 3) larval brook trout drift levels and 4) adult trout spawning population levels. While larval trout drift monitoring and spawning population level studies commenced in 1987-88 the stream utilization levels study was initiated in 1986-1987 as part of an trout habitat inventory and the Floy tagging in 1985-86. The objective of these studies was to monitor brook trout life history stages and strategies throughout the construction of the Limestone Generating Station and for a significant number of years after impoundment to assess the impacts of hydroelectric development on brook trout stocks in the area. This report outlines the study sites, the methods used and the data collected to date. Some discussion of the results is included where qualification of the data are required or modification of the program is recommended.

METHODS

Floy Tagging

Following Gaboury (1978; 1980) all brook trout greater than 17 cm fork length that were sampled and released in the field seasons of 1985-1987 were tagged with individually numbered spaghetti tags. Tags were anchored between interneural spines at the posterior insertion of the dorsal fin. Additionally, a pelvic fin was removed for strontium analyses but also served as a double mark for assessing the tag loss rate. Upon recapture trout location was recorded and trout were identified by tag, weighed, measured and released.

Stream Utilization Levels

Fifteen sites on five Nelson River tributaries were electroshocked in both 1986 and 1987. Three additional sites on CN Creek were shocked only in 1987 (Figure 1). Electroshocking sites were the previously described habitat sections in Moondance, Beaver, Swift, Tiny and Goose Creeks (Swanson and Kansas 1987). The sites on CN Creek were classified with respect to habitat parameters following the methods described in Swanson and Kansas (1987).

Sites were sampled following Swanson and Kansas (1987) wherein the entire 100 m of each site were electroshocked from top to a seine at the bottom if possible. Three passes were done to attempt removal type population estimates (Ricker 1975). If the entire section was not shockable then a portion, or portions of it, were shocked. Accompanying the electroshocker was at least one other person dipnetting and data recording. The length and weight of all trout sampled was measured.

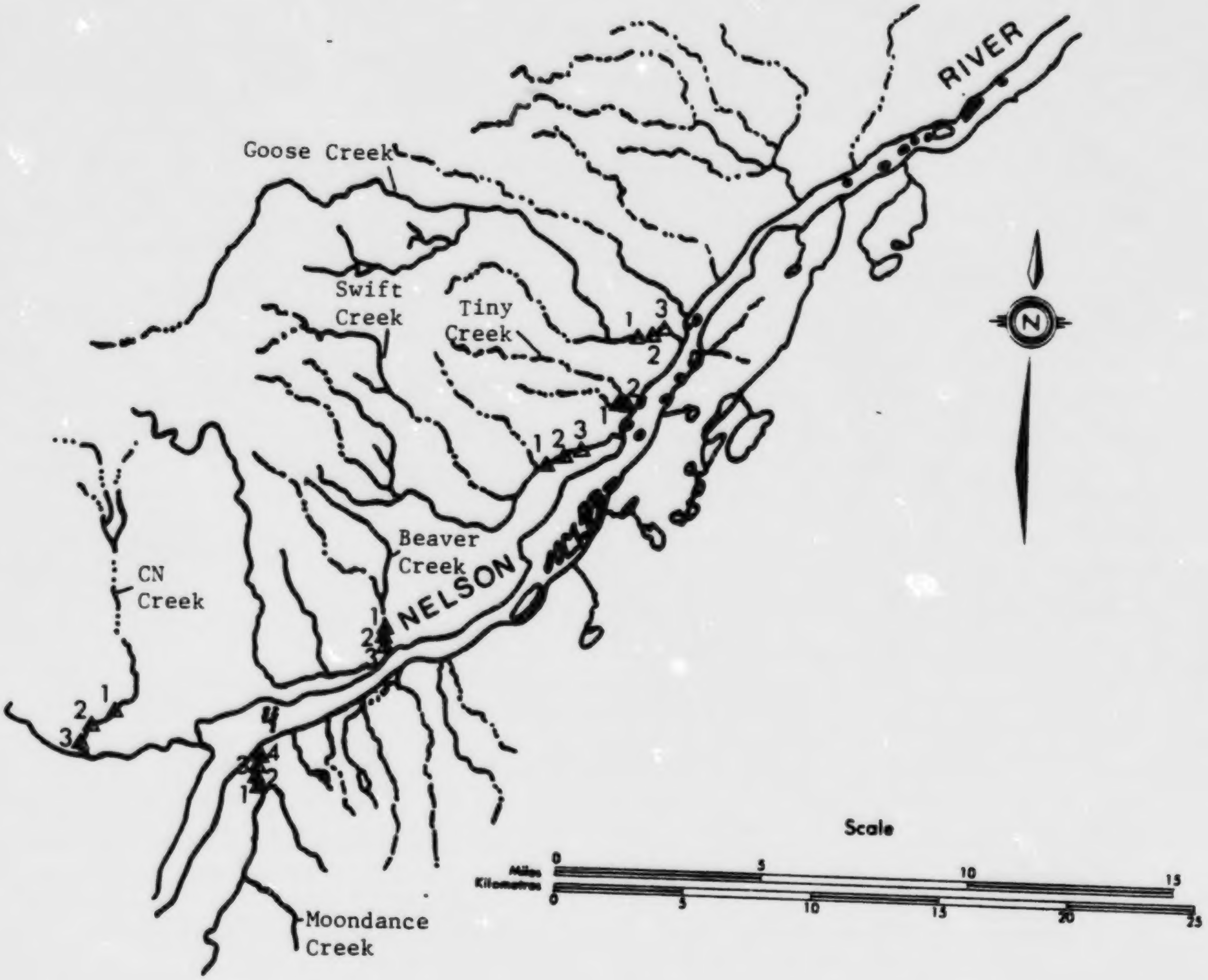

RIVER
NELSON
Goose Creek
Swift Creek
Tiny Creek
Beaver Creek
CN Creek
Moondance Creek
1
2
3
4
N
Scale
Miles
0
5
10
15
Kilometres
0
5
10
15
20
25

Figure 1: Electroshocking sites on Nelson River tributaries in 1987.

For young of the year trout volume displacement was used to estimate weight in the field. Trout longer than 17 cm were also sampled for age (scale sample) and were Floy tagged and released. The frequency of other species sampled were recorded but only brook trout data are reported here.

An additional electroshocking exercise was done in CN Creek in 1987. A mark-recapture experiment was done in the late summer-early fall below habitat section 3 in the immediate vicinity of the spawning area which is associated with groundwater upwellings. Estimates of abundance were calculated using modified Petersen and modified Schnabel estimates (Ricker 1975).

Brook Trout Larval Drift

Larval brook trout were sampled using a total of twelve larval drift traps on three brook trout spawning tributaries in the Limestone Forebay and three spawning tributaries of the Limestone River (Figure 2). Drift trap design was after Burton and Flannagan (1976) and trap placement was approximately 10 cm below the water surface. Forebay tributary and CN Creek traps were sampled daily through the duration of the project (May 12 to June 10). Traps at 12-Mile and 9-Mile were sampled every second day for at least a portion of the sampling period after May 25 due to decreasing water levels and access problems. Sampling entailed collecting all debris collected in each drift trap and a subsequent sorting of the debris and enumeration of the number of brook trout captured at each trap location. Samples were then preserved in a 10% formaldehyde solution.

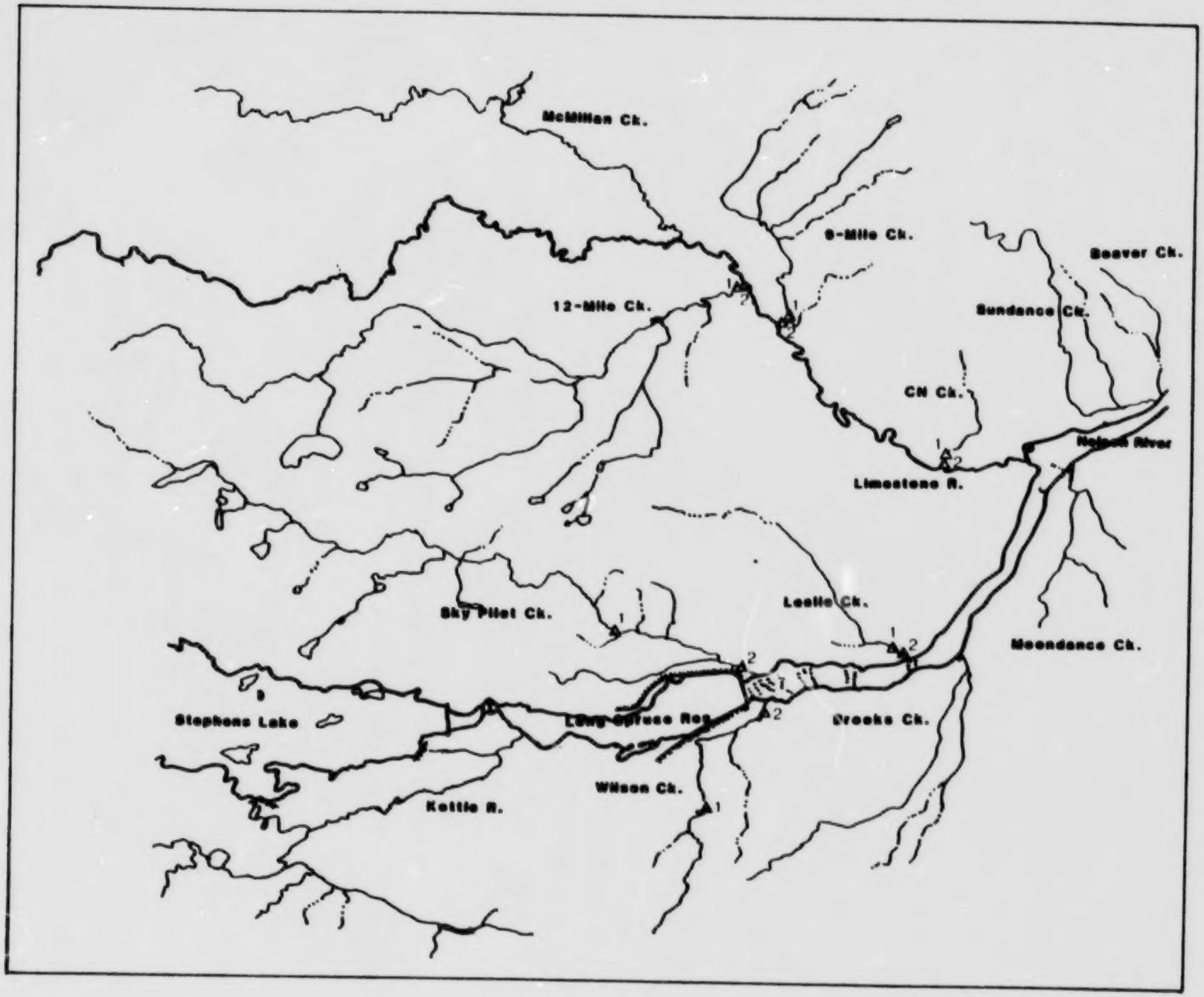

McMillan Ck.
9-Mile Ck.
Beaver Ck.
12-Mile Ck.
Sundance Ck.
CN Ck.
Nelson River
Limestone R.
Leslie Ck.
Sky Pilot Ck.
Moondance Ck.
Stephens Lake
Long Spruce Res.
Brooks Ck.
Wilson Ck.
Kettle R.

Figure 2: Stream drift sampler location for Nelson River tributaries in 1987.

Adult Trout Spawning Populations

Brook trout spawning populations were monitored using two way fish fences on four of the six tributaries sampled for larval drift in 1987 (Figure 3). CN Creek data are not included in this report because the fence (i.e. CN Creek fence 2; see part 2) was pulled in late September and was not of similar construction to the other fences. The Leslie Creek spawning population was not sampled in 1987.

Two way fence installations were completed on all four creeks by August 13, 1988 and fences were sampled thereafter until October 20, 1988. Sampling was done twice daily on Wilson, Sky Pilot and 9-Mile Creeks; once in the morning and again in the evening. 12-Mile Creek was sampled once daily due to access constraints. All trout sampled were weighed (in grams), measured (FL to the nearest millimeter), sampled for ageing structure (scale sample), Floy tagged and released. The trap direction in which the fish was moving when sampled was recorded as was the sampling time and date. Water temperatures were recorded each time the fence was sampled. Fence maintenance was also done each time the fence site was visited and included cleaning accumulated debris off the fence, reinforcing fence support structures, and maintaining fence integrity (i.e. ensuring no holes developed under or around the fence).

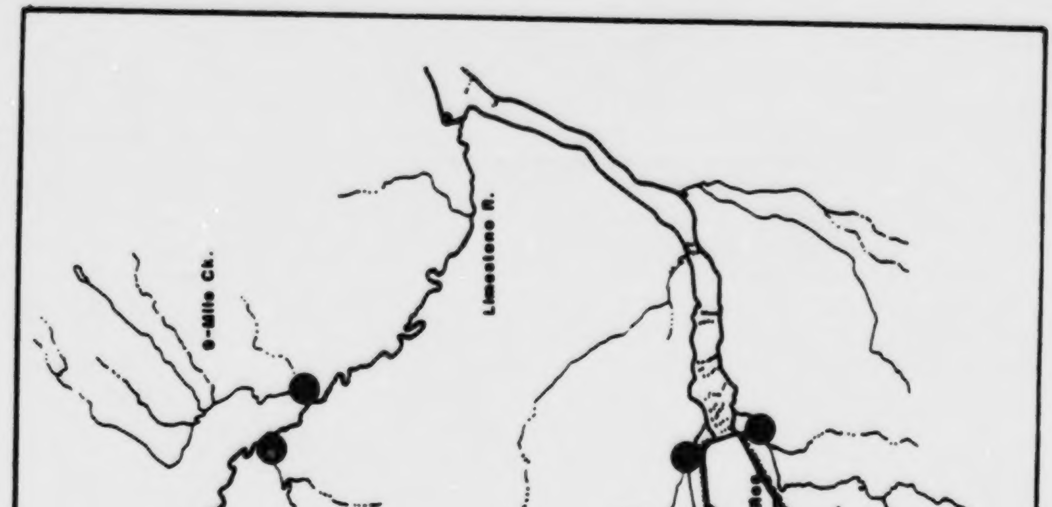

9-Mile Ck.
Limestone R.
12-Mile Ck.
Sky Pilot Ck.
Long Spruce Res.
Wilson Ck.
Stephens Lake

Figure 3: Two way fish fence locations for Nelson River tributaries in 1987.

RESULTS AND DISCUSSIONS

Floy Tag Recapture Data

The total number of brook trout Floy tagged during three field seasons (1985-1987) are summarized by stream and year (Table 1). Individual tag recapture data are outlined in an up to date brook trout recapture summary (Appendix 15). Of the 606 trout Floy tagged in 13 different rivers and creeks, 87 or 14% have been recaptured at least once. Twelve or 14% of the 87 recaptures have been recorded in consecutive years, occassionally in the same location as previously captured and/or originally tagged (eg. spawning grounds). For example, tag number OR00514 was initially tagged on September 3, 1985 in 9-Mile Creek near the spawning pool. It was subsequently recaptured in the spawning pool the following year on September 7 and again in 1987 this fish was caught moving downstream in 9-Mile Creek on September 27. At this date it was spent, presumably having spawned in the upstream pool. Previous studies have also demonstrated a fidelity towards 9-Mile Creek with recaptures in consecutive years (Gaboury 1980; Gaboury and Spence 1981).

In 1987, two-directional fish fences were installed in seven creeks to monitor trout movements. On several occassions in Moondance and Wilson Creeks, trout that were captured and tagged moving upstream, were later recaptured in the same upstream trap (eg. #OR00459). This "phenomenon" indicates inefficiences in some fence operations which need to be corrected.

Brook trout also demonstrated multiple stream use in 1987 as

Table 1: Brook trout floy tagging summary for years 1985-1987.

Stream Name	1985	1986	1987	Total
Limestone River	29	14	7	50
Nine-mile Creek	28	4	59	91
Twelve-mile Creek	5	0	21	26
CN Creek	2	0	71	73
Bird Creek	2	0	0	2
Sky Pilot Creek	83	0	25	108
Wilson Creek	7	0	99	106
Leslie Creek	0	1	0	1
Moondance Creek	41	4	61	106
Sundance Creek	2	0	0	2
Beaver Creek	0	0	2	2
Swift Creek	4	0	0	4
Weir River	0	35	0	35
Total	203	58	345	606

noted for tag #I001439 results. Originally tagged on September 10th at Moondance Creek, this trout was recaptured seventeen days later at 5-Mile Hole on the Limestone River. This trout was subsequently radio tagged (48.117 Mhz) and transferred to Long Spruce Reservoir as part of the study on the effects of impoundment on brook trout.

Three radio tag frequencies are shown in the brook trout recapture summary. These trout were recaptured by anglers and eventually turned in to Natural Resources staff. Since tagging started in 1985, 8 Floy tags have been returned to us or the Natural Resource Officers of the area.

Some brook trout had to be re-tagged when recaptured because the Floy tag was not securely anchored or was missing. Overall the combined total tag loss rate was approximately 8% (9 out of 104 recaptures). Keller (1971) found that the major cause of a low tag retention percentage in brook trout was improper placement of the tag. Engagement of the interneural bones must take place for the tag to anchor properly.

Carline and Brynidlson (1972) comment on the effect of Floy tags on growth and survival in brook trout. They found that some negative effect on growth occurs from October-January in 10 month old domesticated brook trout, with no effect on survival. We have used tricaine methaneusulfonate (MS222) to ease the tagging process when large numbers of fish were involved. Houston et al. (1971) found that brook trout anaesthesized with MS222 experienced some changes in electrolyte concentrations combined with a depressive influence on the central autonomic functions. Since MS222 takes hours to completely clear from the system, Houston et al. (1971) stress an adequate recovery period. This is not always a precaution which we are able to follow. It is therefore recommended that tagging take place without the use of anaesthetics.

Stream Utilization Levels

Total brook trout densities sampled in all stream habitat sections were 1.1 x 10^{-7} trout.m$^{2^{-1}}$.sec^{-1} in 1986 and 6.3 x 10^{-7} trout.m$^{2-1}$.sec^{-1} in 1987. When these figures were corrected for the same creek sections sampled in both years similar differences were observed with combined values of 1.5x10^{-7} trout per unit effort in 1986 and 6.7x10^{-7} trout per unit effort in 1987 (Table 2). CPUE in weight was however lower in 1987. This is because the trout sampled in 1987 were 1+ years or younger and the capture of one large trout in 1986 in Moondance Creek section 3 at 350g greatly influenced the combined total CPUE in grams. Data for both years sampled are presented by stream section in Figures 4 and 5.

Perhaps the most ecologically significant observation is the relative abundance of young of the year brook trout sampled in 1987 primarily in Moondance Creek sections. The reason for these increased levels is believed to be the presence of a large beaver dam immediately downstream of the spawning area. This beaver dam greatly increases pool volume in the area and also provides sanctuary from peak spring flows which would otherwise serve to disperse trout fry downstream in the spring. Utilization levels for Beaver Creek also indicated increased brook trout use which may be a result of increased survival due to a somewhat milder winter in 1986-87 than in 1985-86.

Table 2: Electrofishing data for habitat sections included in long term monitoring studies. CPUE = catch per unit effort.

		1986						1987					
Section		Area Shocked	Seconds Shocked	Total Number of Trout	Trout CPUE (no.·m$^{2-1}$·sec^{-1})	Total Weight of Trout(g)	Trout CPUE (g·m$^{2-1}$·sec^{-1})	Area Shocked	Seconds Shocked	Total Number of Trout	Trout CPUE (no.·m$^{2-1}$·sec^{-1})	Total Weight of Trout	Trout CPUE (g·m^{2} $^{-1}$·sec^{-1})
Moondance	1	392	380	0	0	0	0	670	250	3	179.1x10^{-7}	20	119.4x10^{-6}
	2	477	309	1	67.9x10^{-7}	9	61.1x10^{-6}	544	2199	29	242.4x10^{-7}	196	163.8x10^{-6}
	3	300	464	3	215.5x10^{-7}	362	2,600.6x10^{-6}	522	389	10	492.5x10^{-7}	196	965.2x10^{-6}
	4	566	410	0	0	0	0	660	450	5	1,178.5x10^{-7}	35	117.8x10^{-6}
Beaver	1	185	225	0	0	0	0	440	970	0	0	0	0
	2	208	205	0	0	0	0	320	759	1	41.2x10^{-7}	6	24.7x10^{-6}
	3	148	222	1	304.4x10^{-7}	9	273.9x10^{-6}	320	700	4	178.6x10^{-7}	130	580.4x10^{-6}
Swift	1	216	661	0	0	0	0	603	375	0	0	0	0
	2	490	339	0	0	0	0	830	655	0	0	0	0
	3	462	868	0	0	0	0	730	595	0	0	0	0
Tiny	1	44	273	1	832.5x10^{-7}	150	12,487.5x10^{-6}	315	301	0	0	0	0
	2	264	550	0	0	0	0	260	472	0	0	0	0
Goose	1	388	891	0	0	0	0	660	291	0	0	0	0
	2	322	1233	0	0	0	0	490	401	0	0	0	0
	3	514	873	0	0	0	0	680	850	0	0	0	0
CN	1	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	220	1084	3	125.8x10^{-7}	47	197.1x10^{-6}
	3	-	-	-	-	-	-	195	653	6	471.2x10^{-7}	239	1,876.9x10^{-6}
Combined[a]		4976	7903	6	1.5x10^{-7}	530	13.4x10^{-6}	8044	9657	52	6.7x10^{-7}	583	7.5x10^{-6}

[a] - excluding CN Creek.

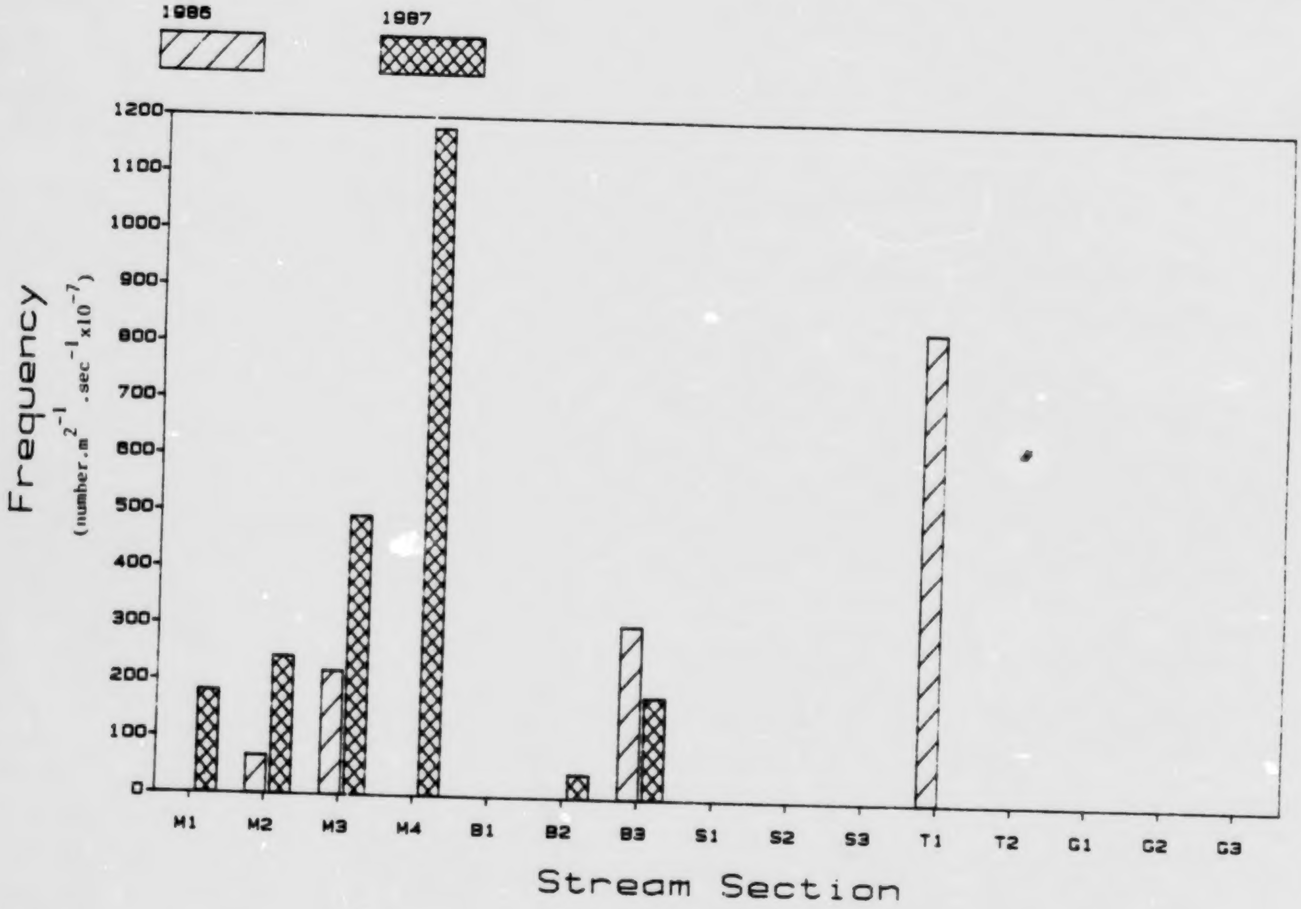


Figure 4: Catch per unit effort data for the number of trout sampled in 1986 and 1987 in stream habitat sections.

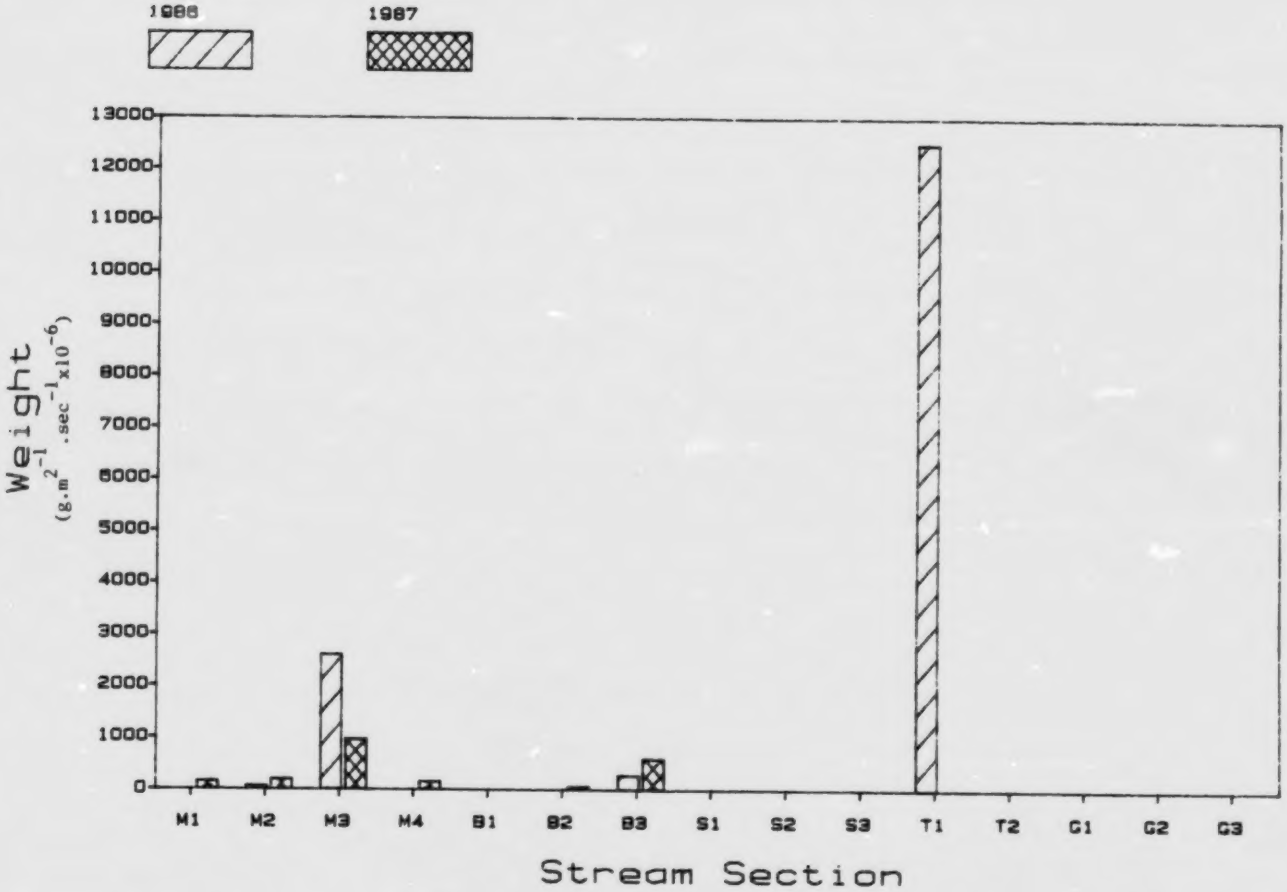


Figure 5: Catch per unit effort data for the biomass of trout sampled in 1986 and 1987 in stream habitat sections.

The reason that CPUE overall is low is that the distribution of juvenile brook trout in the area is highly contagious and 1800 m of stream length sampled is small. A contagious distribution is supported by the data collected wherein many 100 m sections sampled no trout and others sampled many. Further proof of this was found by doing a mark-recapture experiment in the lower 400 m of CN Creek in late summer-early fall of 1987 (see part 2). In fact in the neighborhood of 650 juvenile brook trout were observed to inhabit this stream section. The primary environmental circumstance which facilitated these high trout densities was the preponderance of groundwater intrusion sites; a coincidence that was supported by Latta (1969). The implication of this to the monitoring program is that monitoring of juvenile trout utilization levels in known groundwater areas should also be undertaken on an annual basis.

Brook Trout Larval Drift

The frequencies of brook trout sampled in larval drift bombs are presented by trap in Figures 6-10. Obvious by their absence are 12-Mile Creek traps and the Wilson Creek trap 2. This is because larval trout were not sampled in these traps. An obvious anomoly is the fact that CN Creek traps sampled a total of 50 larval brook trout and 12-Mile Creek traps sampled none. This is probably a function of the fact that 12-Mile Creek has a mean annual discharge in the order of nine times that for CN Creek. Hence drift traps sampled less of the total flow and more fry would have drifted past the traps (i.e. less effeciently sampling the total drift) in 12-Mile Creek. Furthermore, because stage : discharge relationships were not established no estimates of

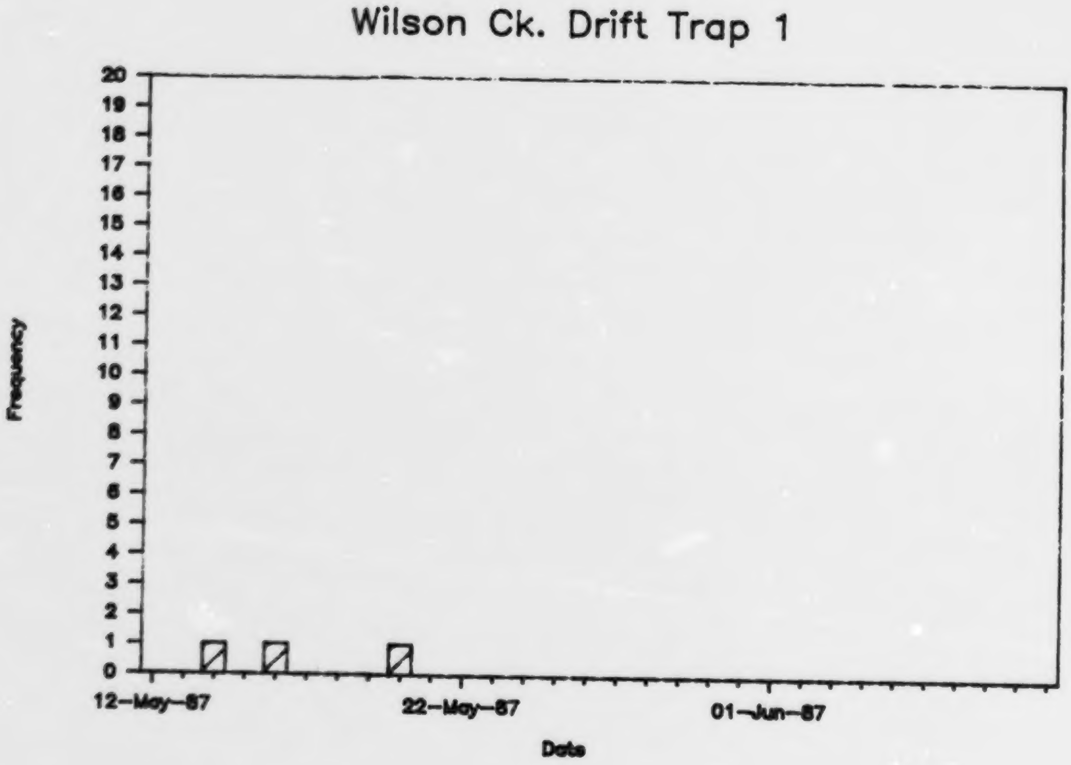
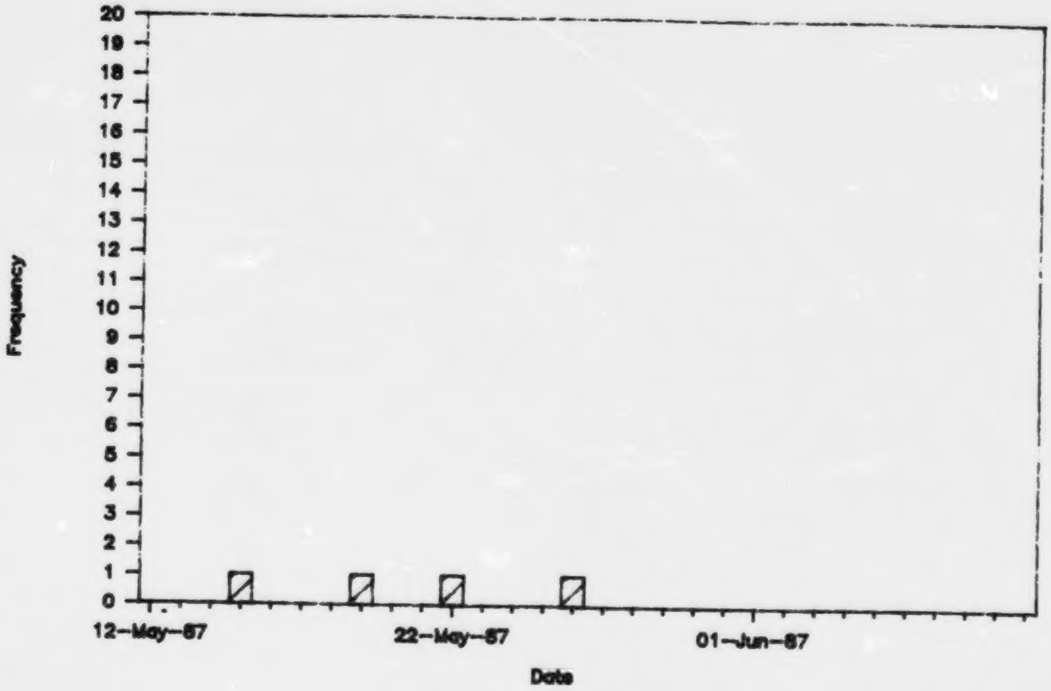


Figure 6: Frequency of larval brook trout sampled in Wilson Creek drift trap 1.

CN Ck. Drift Trap 1



CN Ck. Drift Trap 2

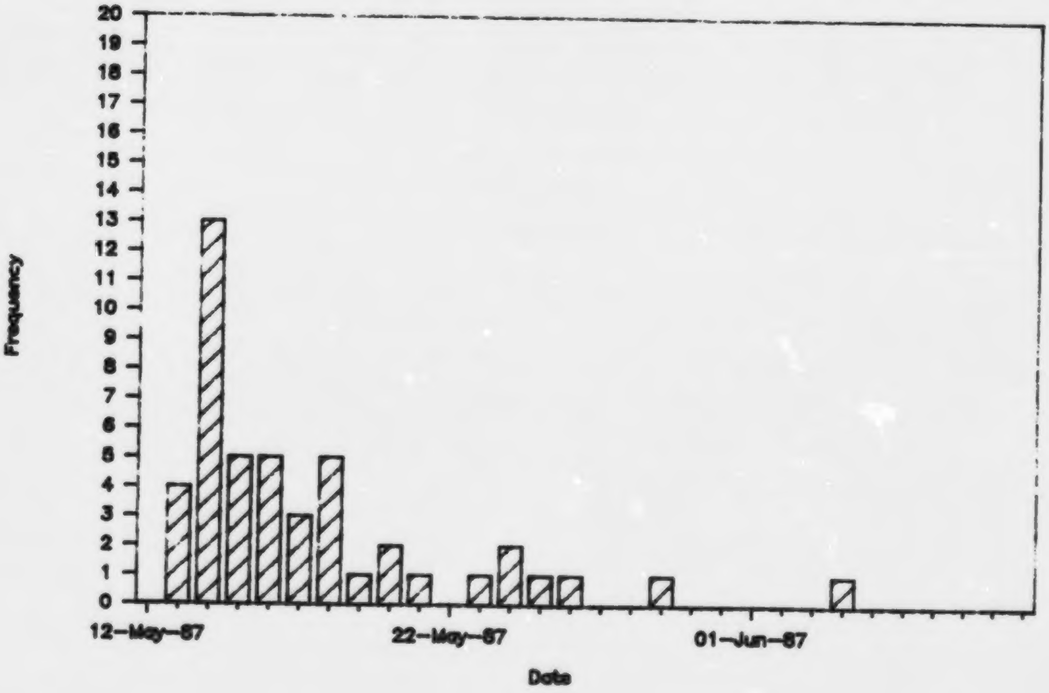
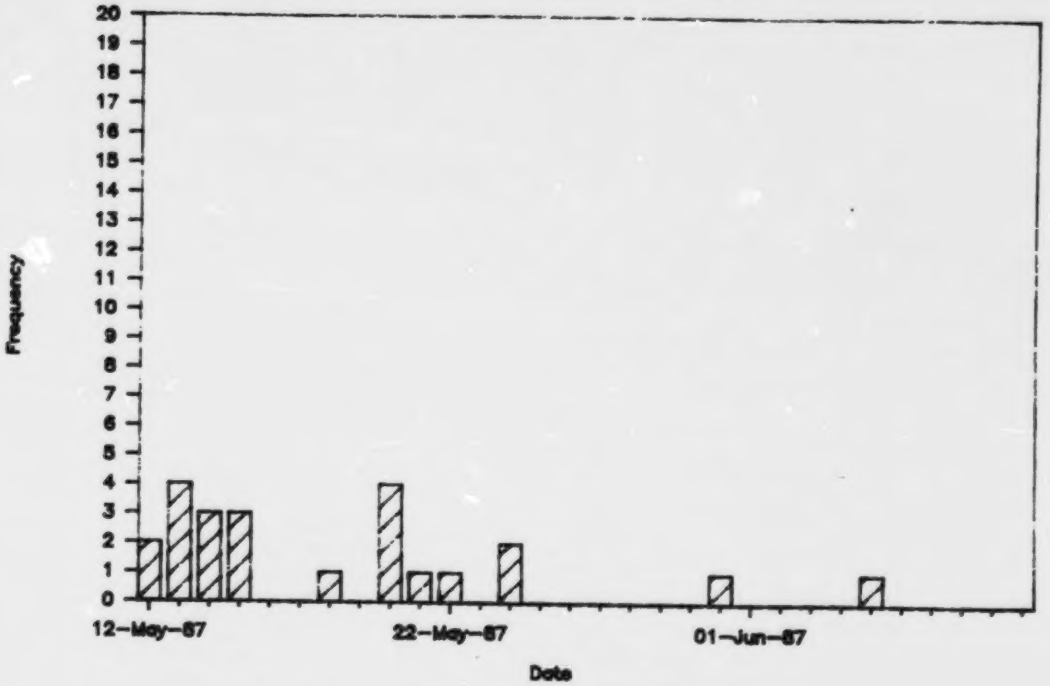
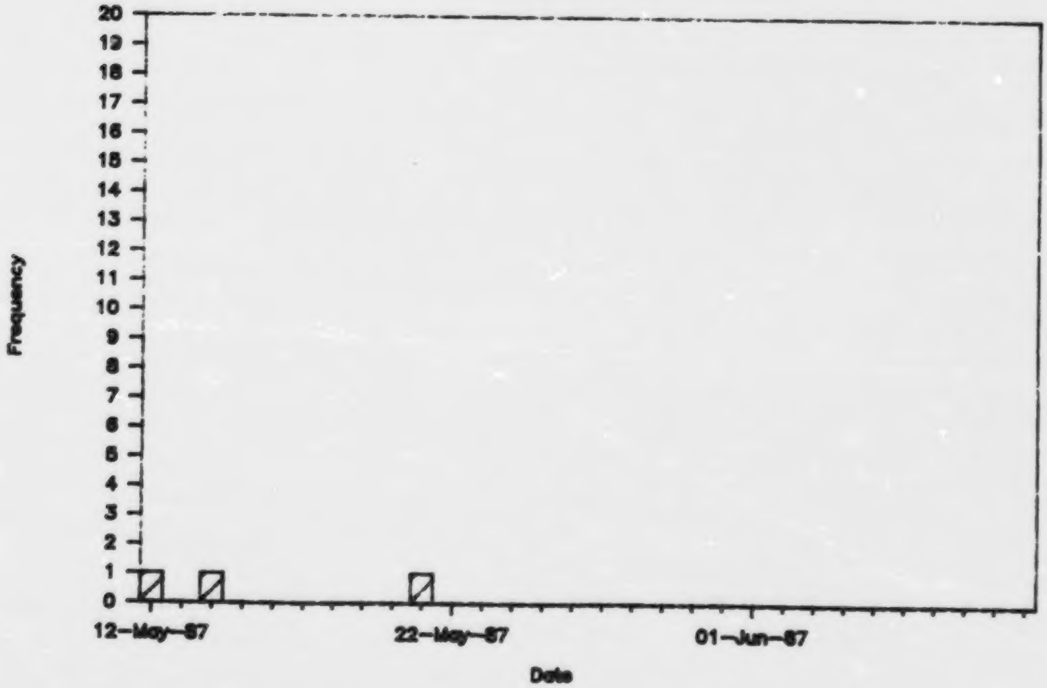


Figure 7: Frequency of larval brook trout sampled in CN Creek traps 1 and 2.

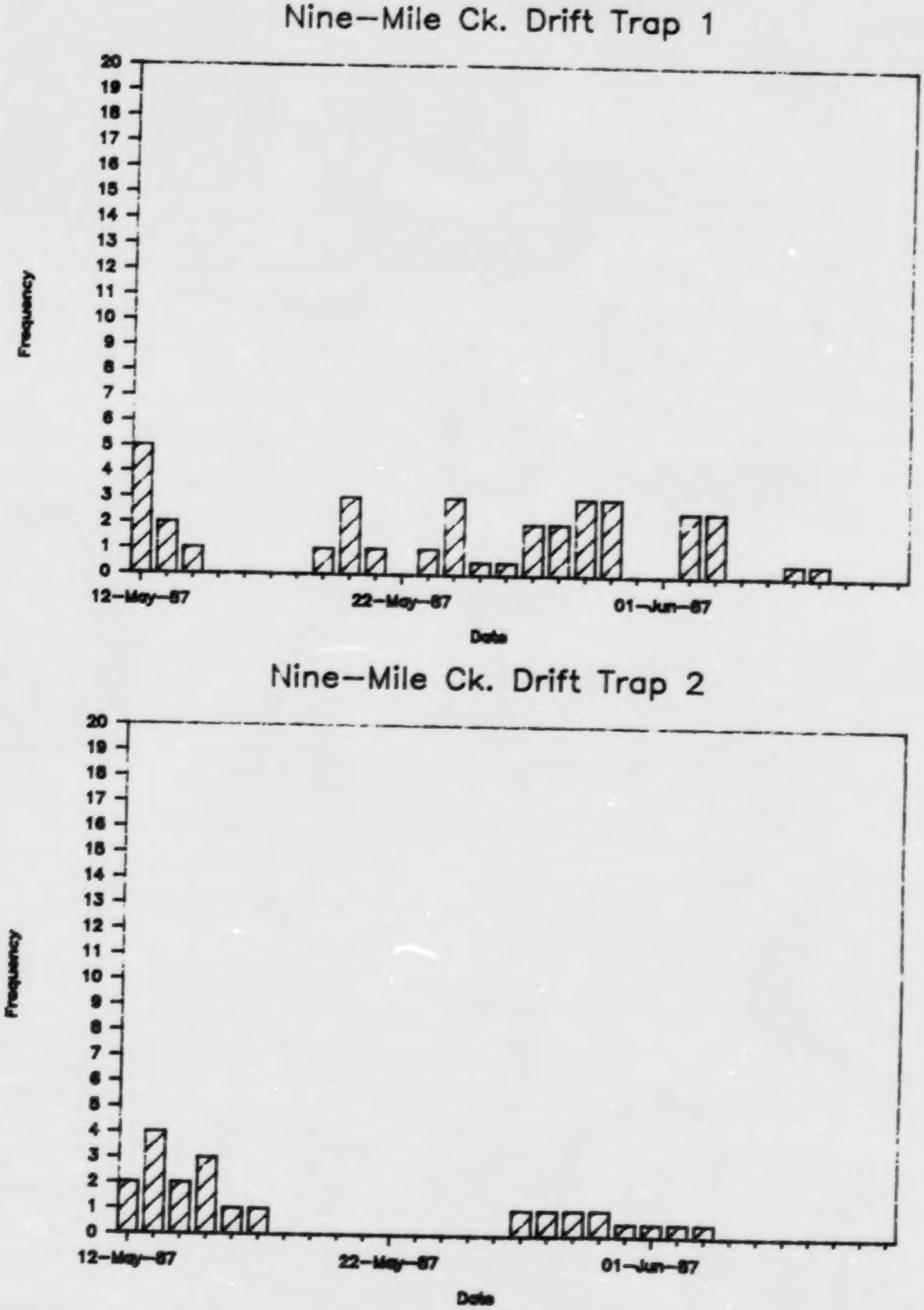


Sky Pilot Ck. Drift Trap 1



Sky Pilot Ck. Drift Trap 2

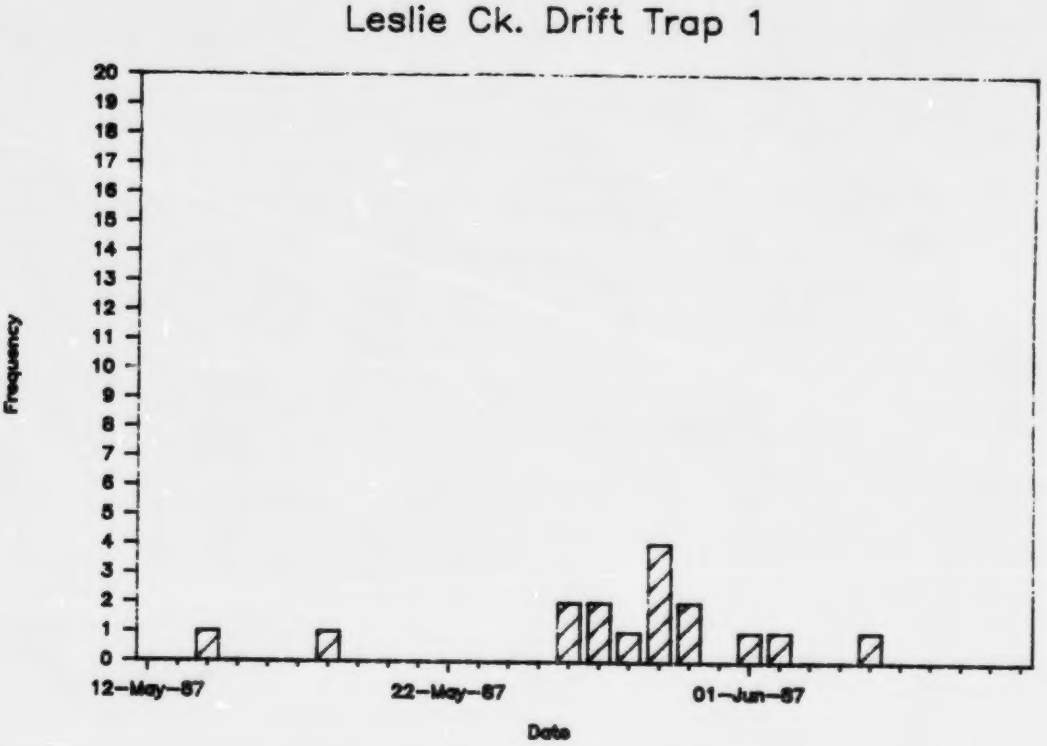
Figure 8: Frequency of larval brook trout sampled in Sky Pilot Creek drift traps 1 and 2.



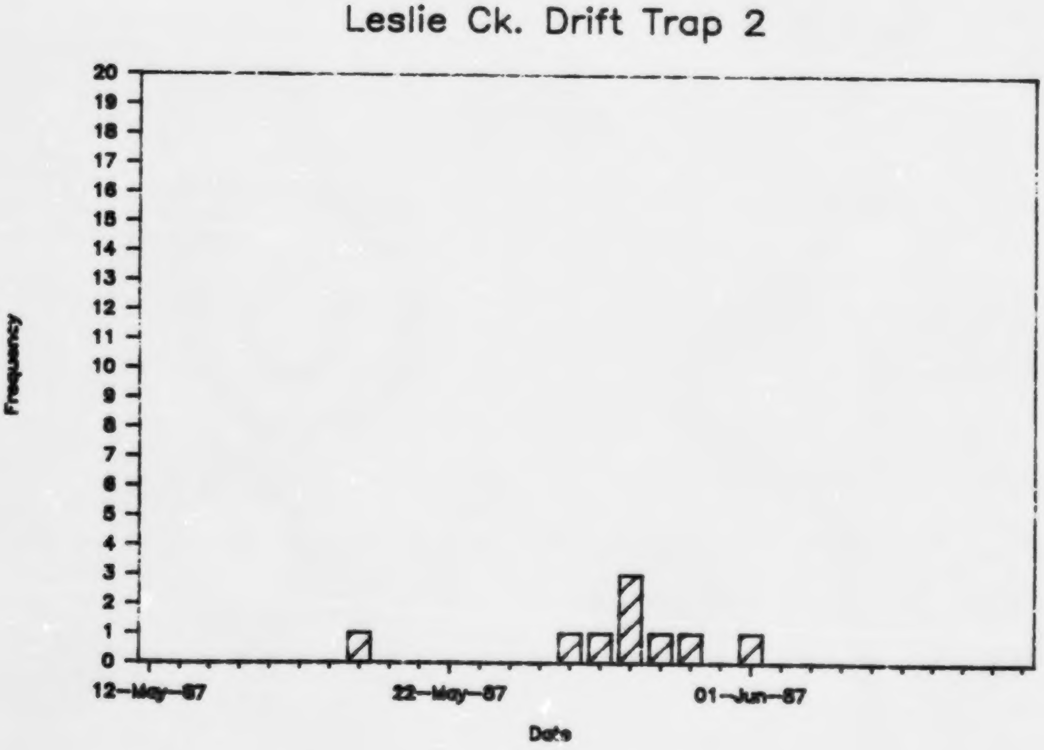
Nine-Mile Ck. Drift Trap 1

Nine-Mile Ck. Drift Trap 2

Figure 9: Frequency of larval brook trout sampled in Nine-Mile Creek drift traps 1 and 2.



Leslie Ck. Drift Trap 1



Leslie Ck. Drift Trap 2

Figure 10: Frequency of brook trout sampled in Leslie Creek drift traps 1 and 2.

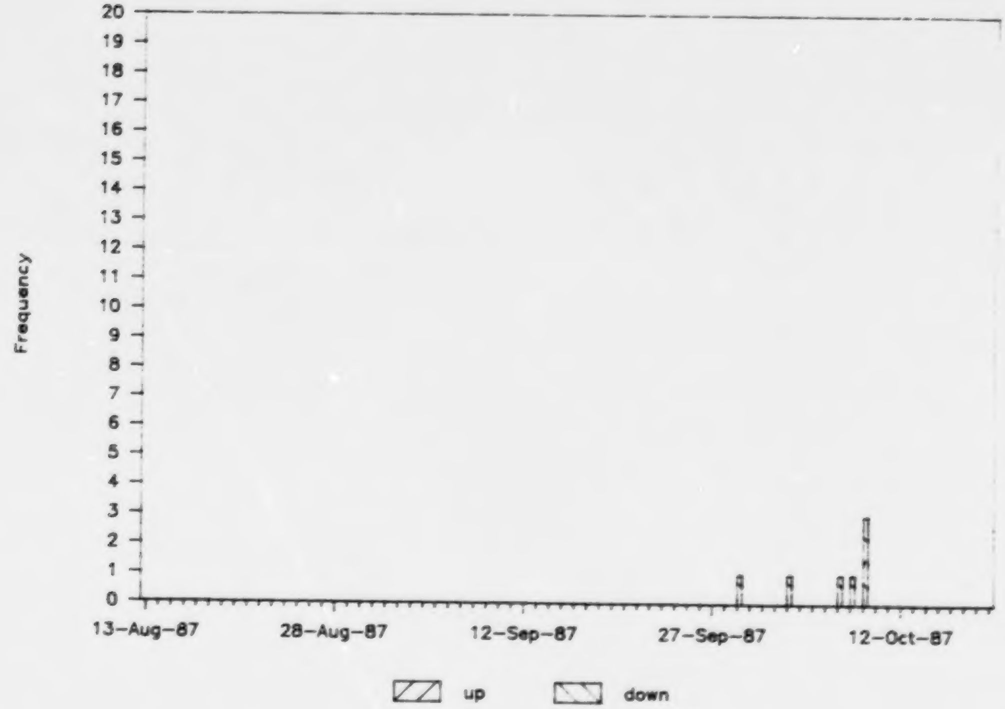
these differences can be made. This is clearly an additional aspect of the larval drift sampling program which must be implemented in subsequent years.

Also of interest is the fact that peak trout fry drift in Leslie Creek occurred later in the spring than on 9-Mile, Sky Pilot and CN Creeks. Perhaps environmental factors such as temperature or oxygen concentration in groundwater differentially altered trout development rates in Leslie Creek. These factors have been documented to effect embryo development in brook trout (Garside 1966).

Adult Trout Spawning Populations

Data for the movement of trout upstream and downstream past the two way fish fences is presented in Figures 11-18. It should be noted that the frequency of 0.5 trout in 12-Mile Creek on September 7-8 and October 12-13 correspond to dates when crew shift changes and helicopter availability could not be coordinated. For this reason the catches on September 8 and October 13 were averaged for those days and the unsampled day preceding.

Of interest is the fact that Wilson and 9-Mile Creeks sampled pulses of small trout moving downstream in the daytime (i.e. p.m. data). These pulses were in both cases associated with a rapid decline in water temperature (Figures 19 and 20). Sky Pilot Creek and 12-Mile Creek fish fences sampled much fewer trout over the same range in dates and temperatures (Figures 21 and 22). In total 25, 95, 21 and 58 brook trout were sampled in Sky Pilot, Wilson, 12-Mile and 9-Mile Creeks respectively.


Wilson Creek a.m. frequency data.

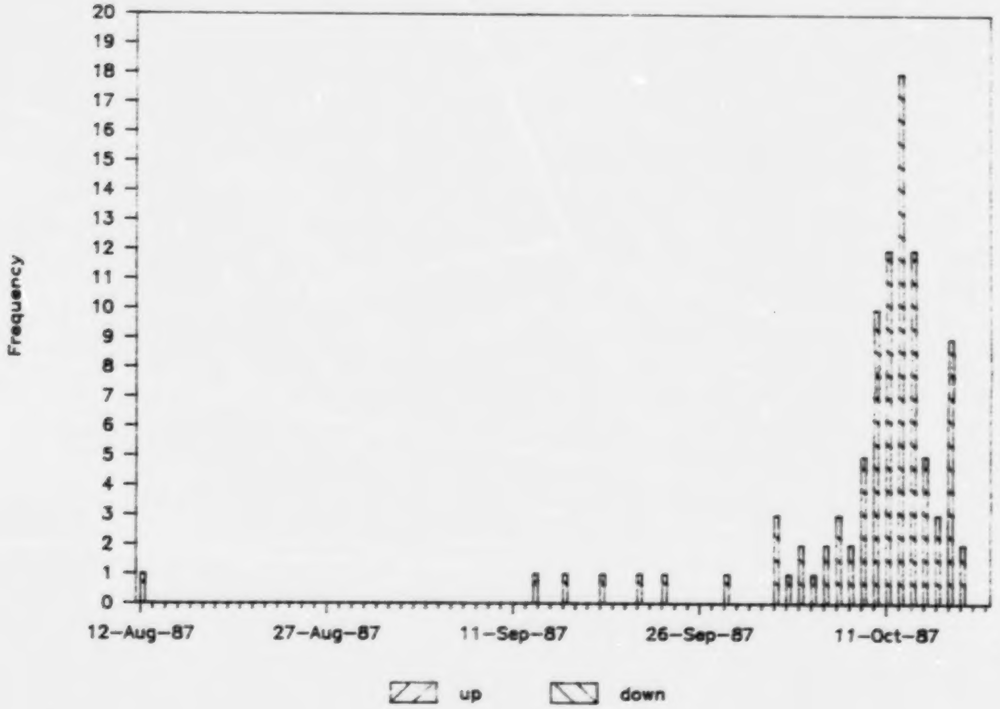
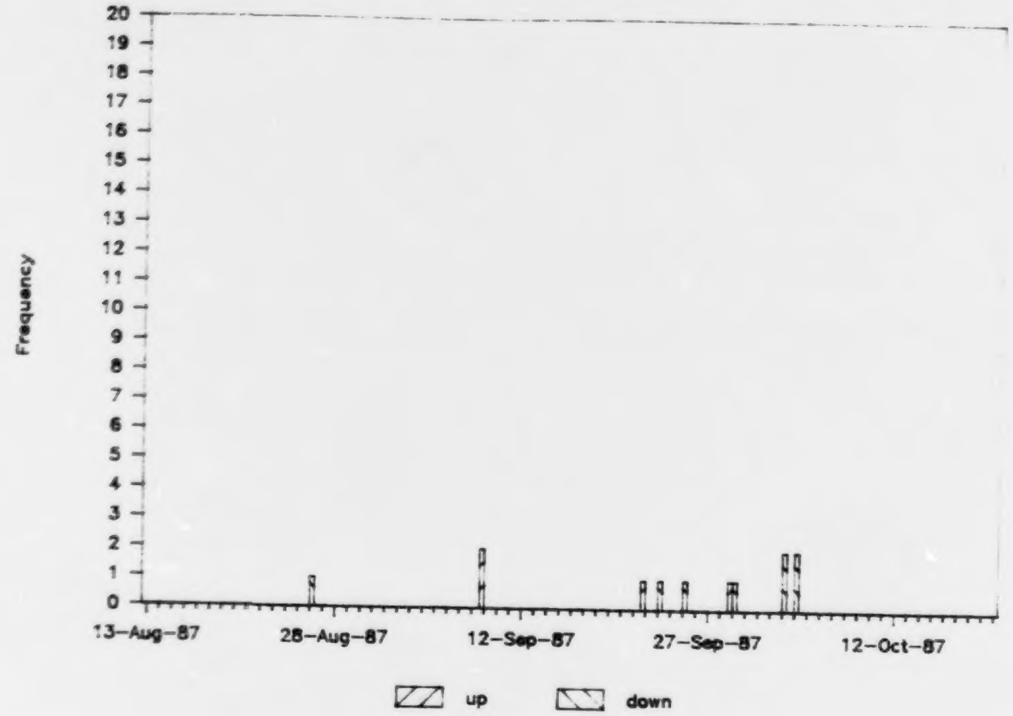
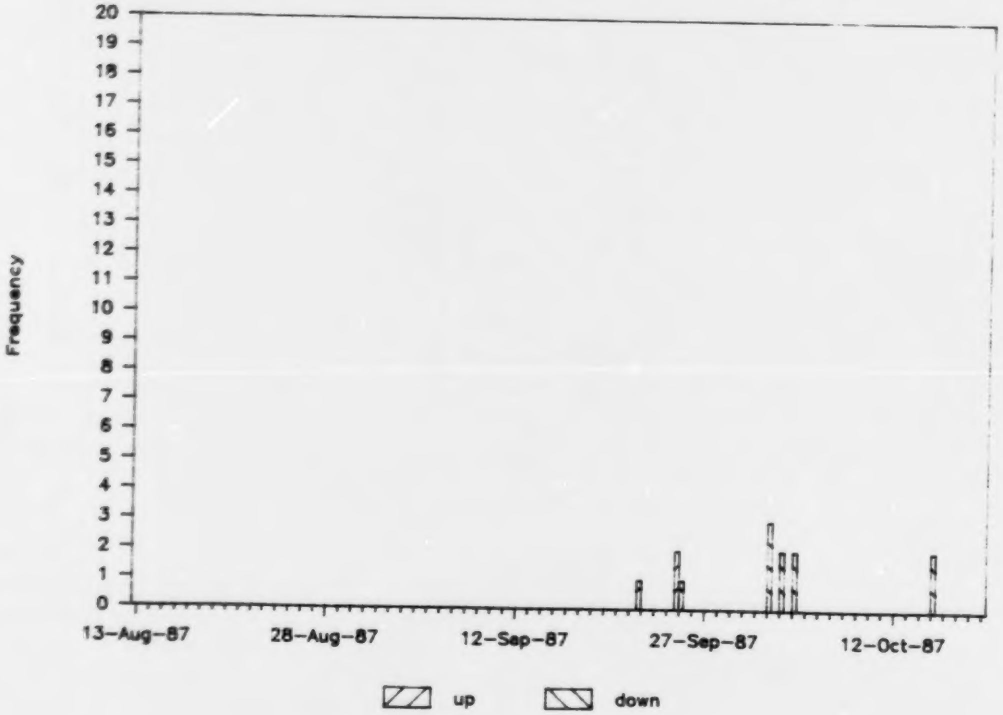

Wilson Creek p.m. frequency data.

Figure 11: Trout frequencies in the Wilson Creek fish fence.

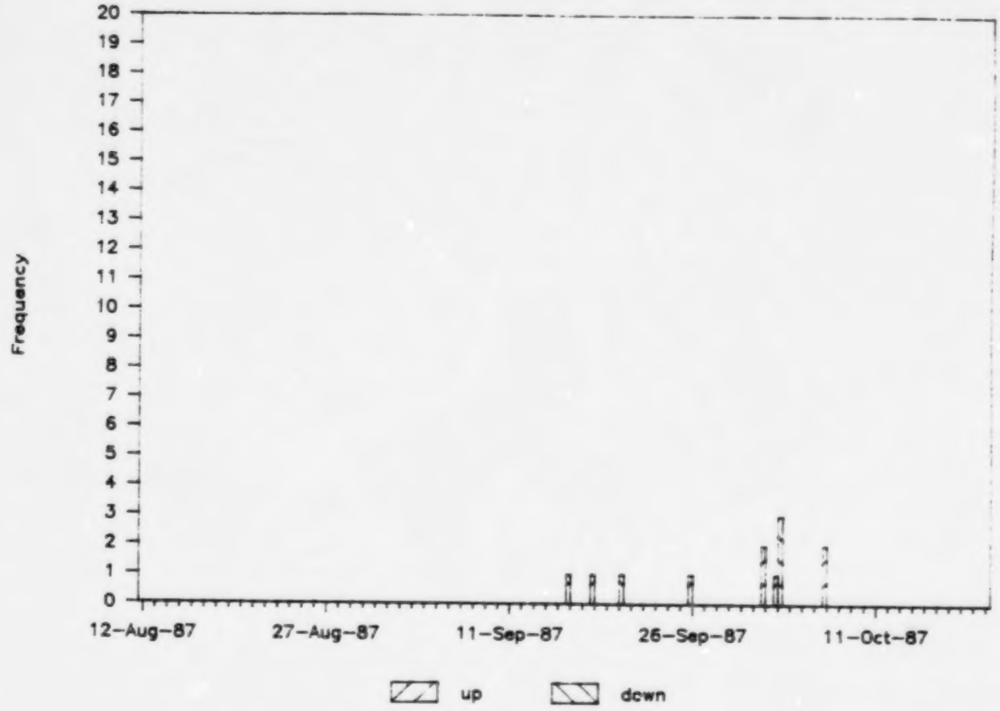


Sky Pilot Creek a.m. frequency data.

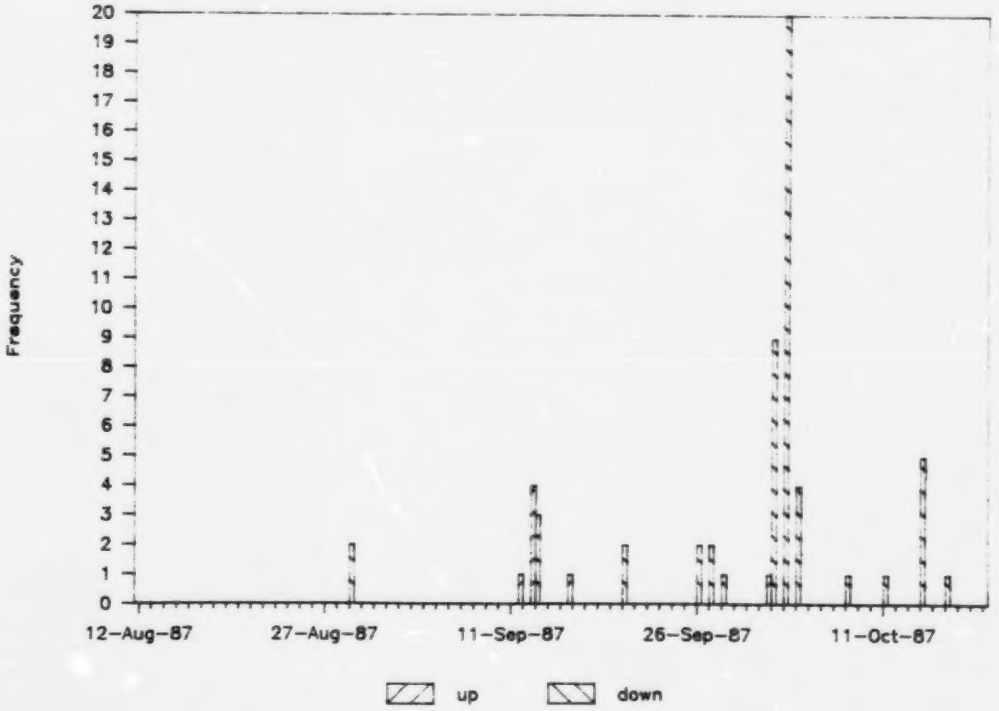


Sky Pilot Creek p.m. frequency data.

Figure 12: Trout frequencies in the Sky Pilot Creek fish fence.



9—Mile Creek a.m. frequency data.



9—Mile Creek p.m. frequency data.

Figure 13: Trout frequencies in the 9-Mile Creek fish fence.

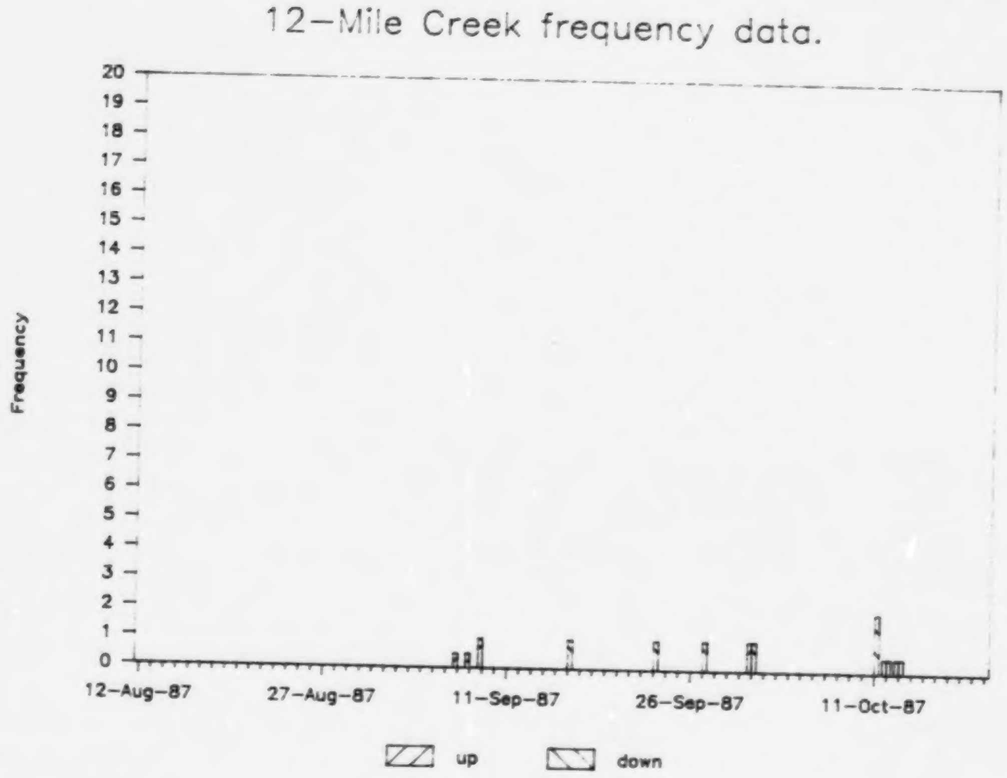
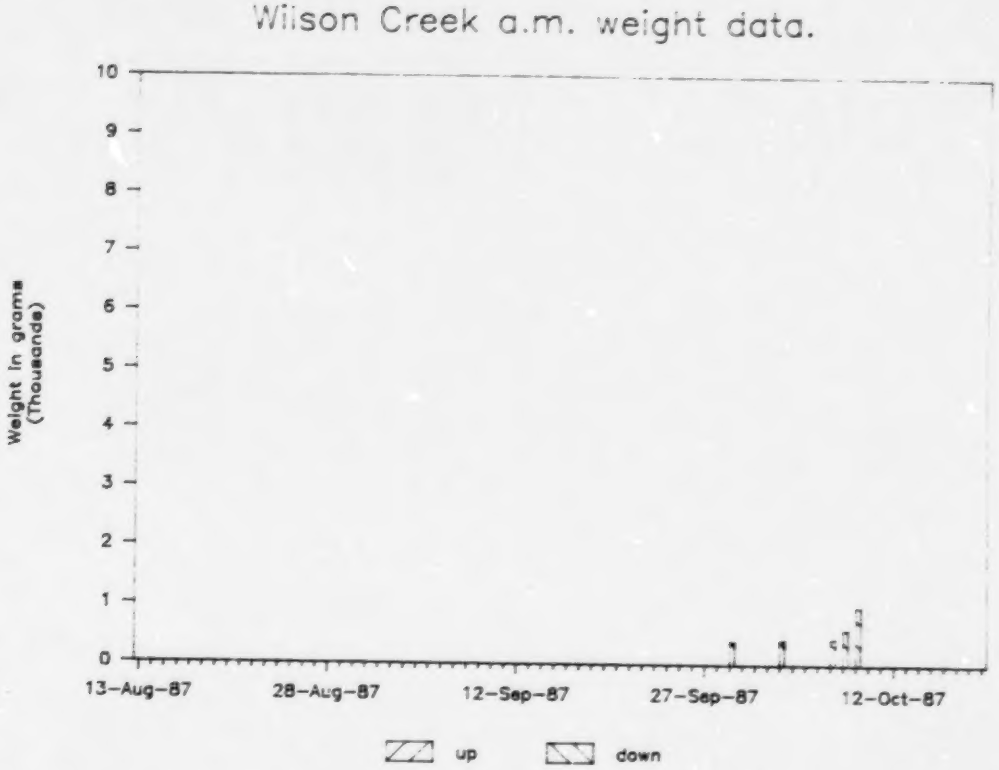
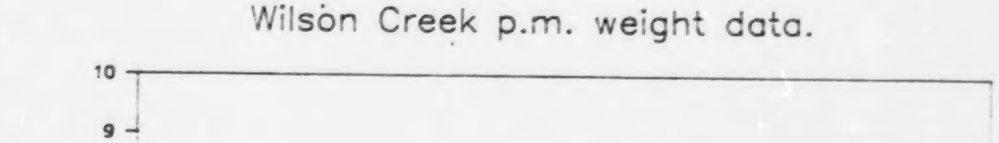


Figure 14: Trout frequencies in the 12-Mile Creek fish fence.

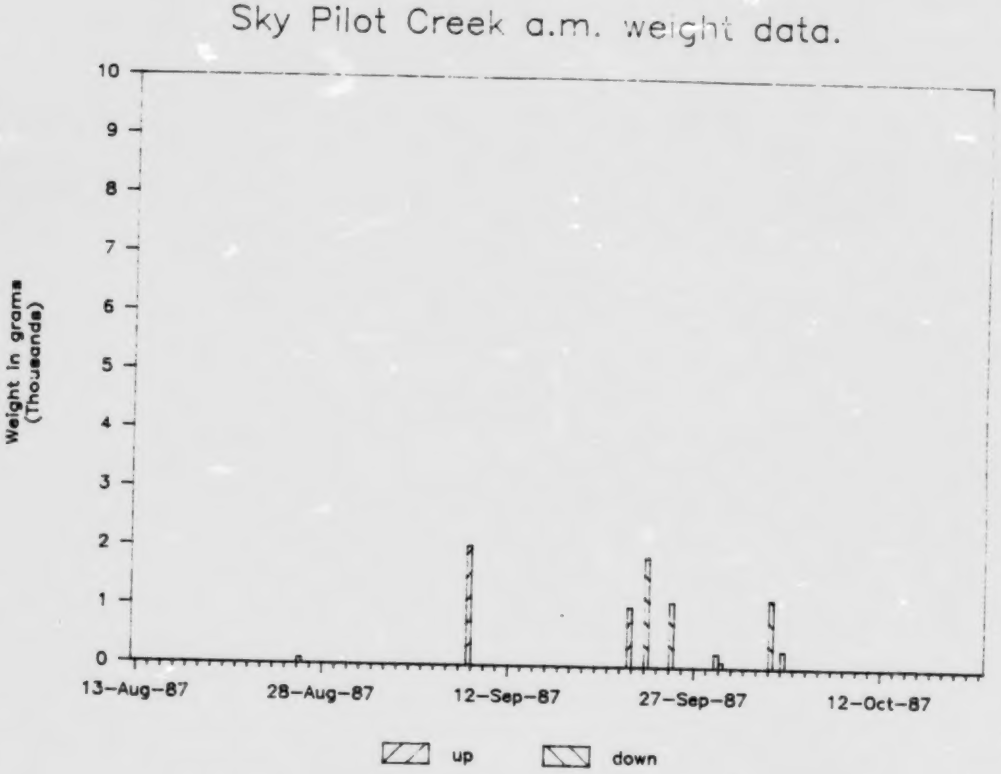


Wilson Creek a.m. weight data.

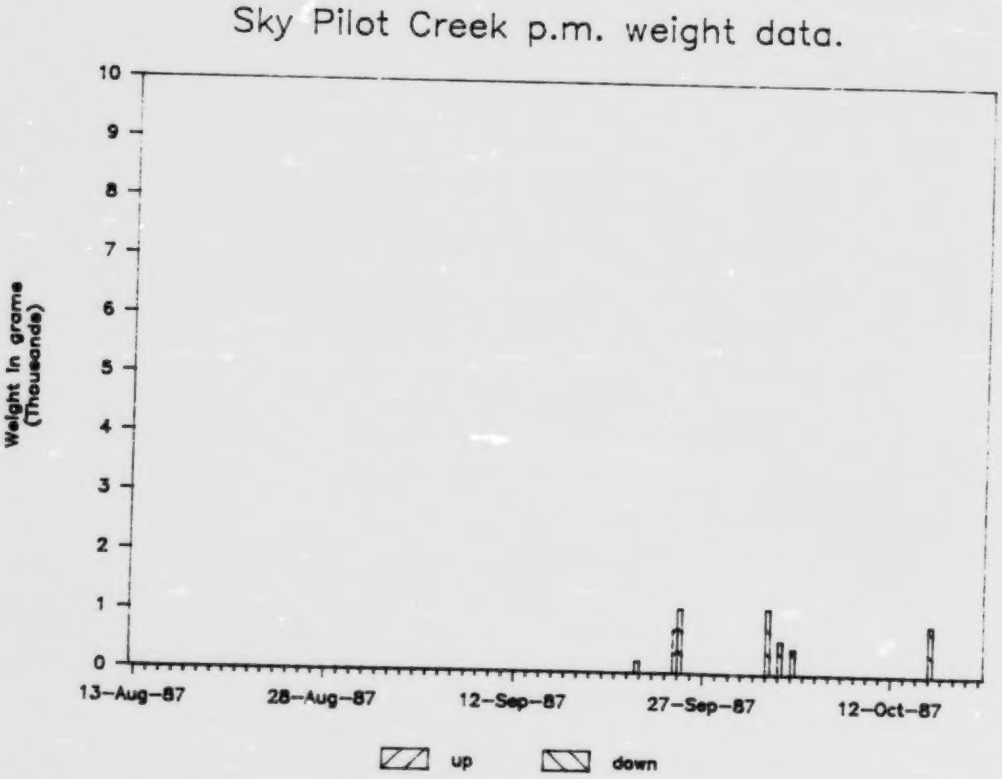


Wilson Creek p.m. weight data.

Figure 15: Trout biomass sampled in the Wilson Creek fish fence.

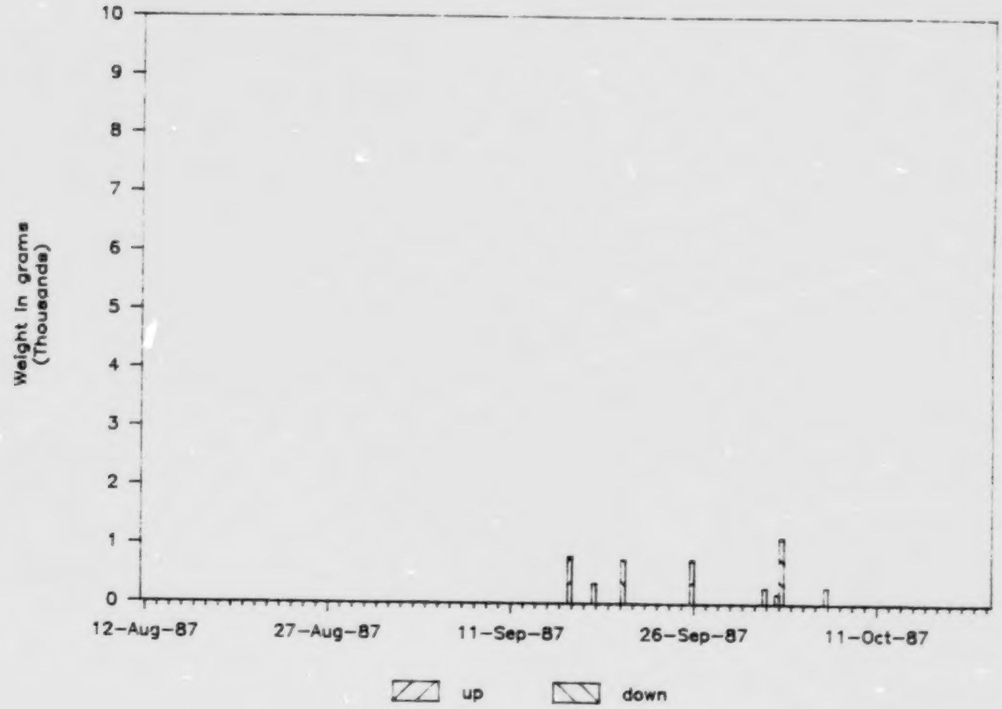


Sky Pilot Creek a.m. weight data.



Sky Pilot Creek p.m. weight data.

Figure 16: Trout biomass sampled in the Sky Pilot Creek fish fence.


9-Mile Creek a.m. weight data.

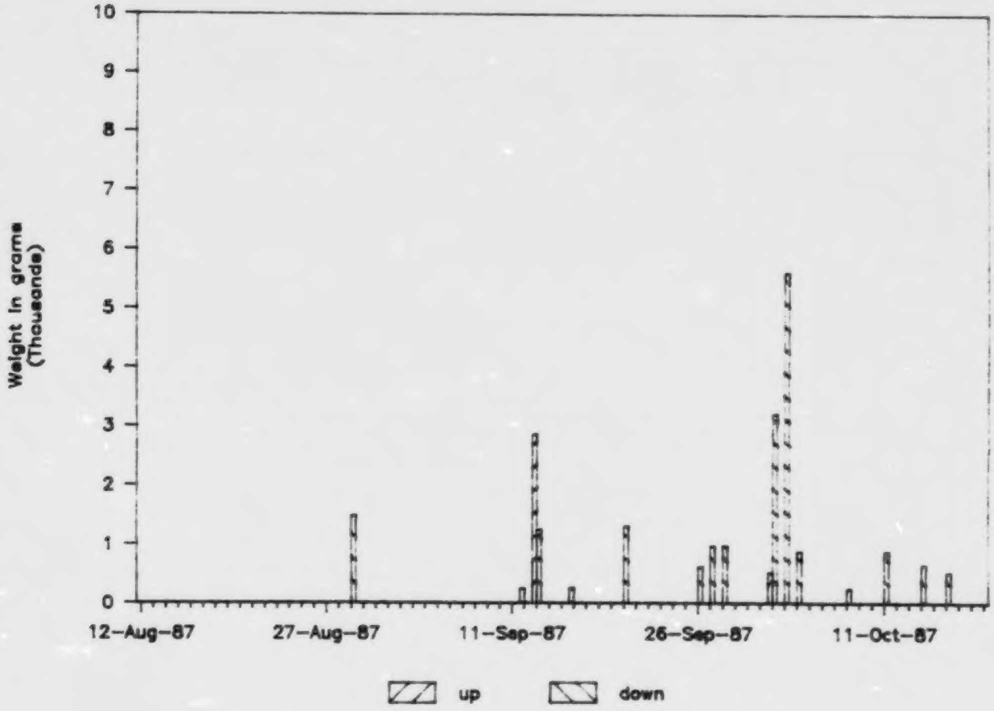

9-Mile Creek p.m. weight data.

Figure 17: Trout biomass sampled in the 9-Mile Creek fish fence.

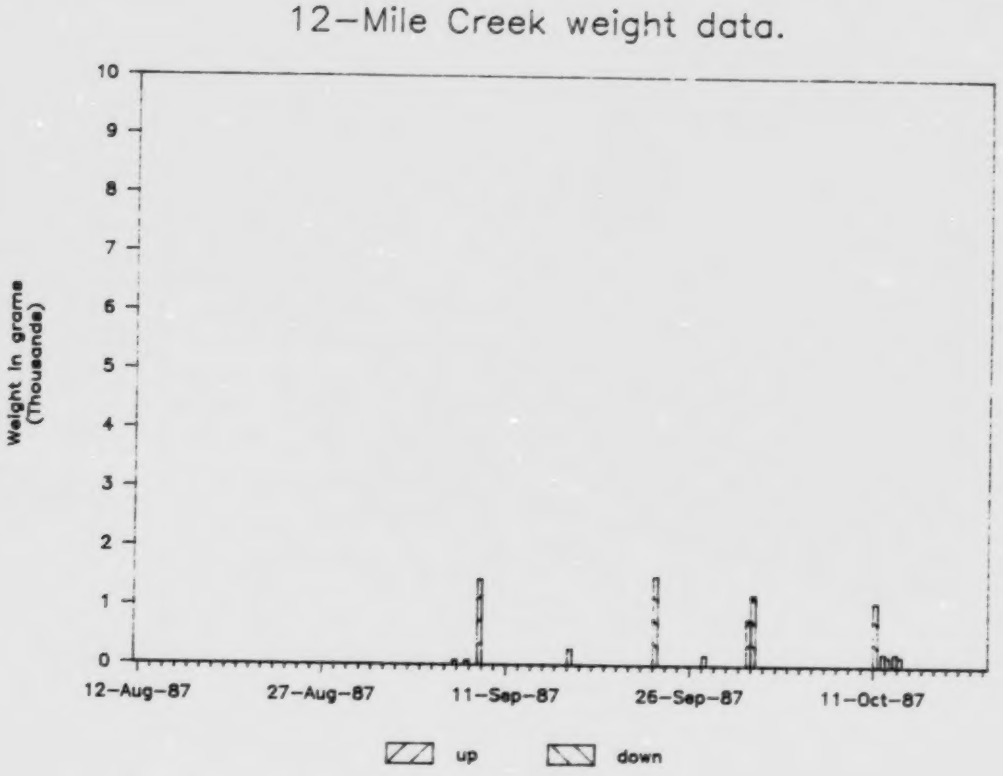
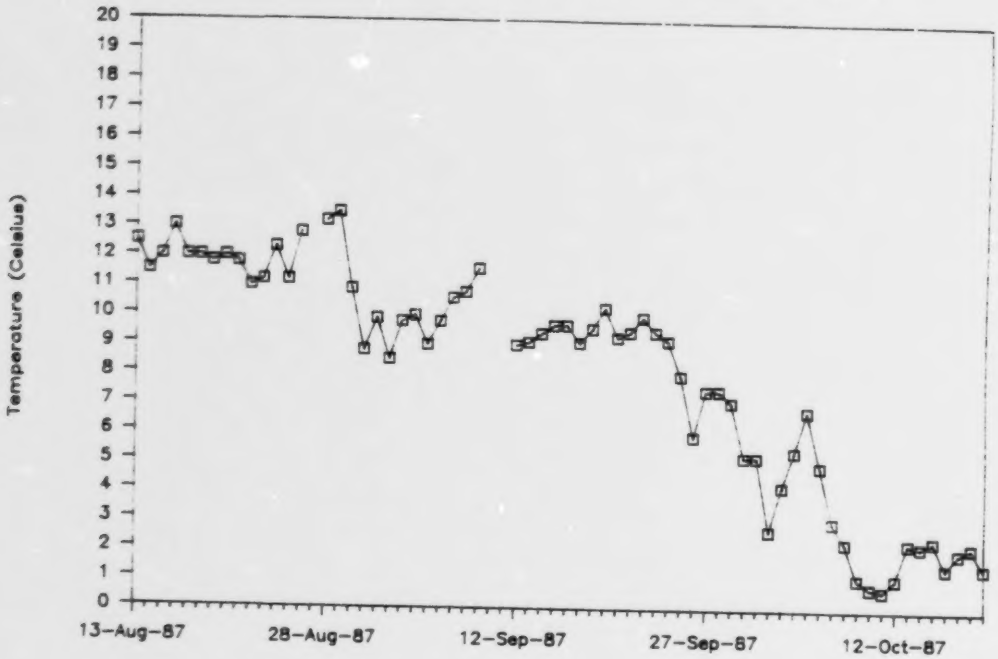
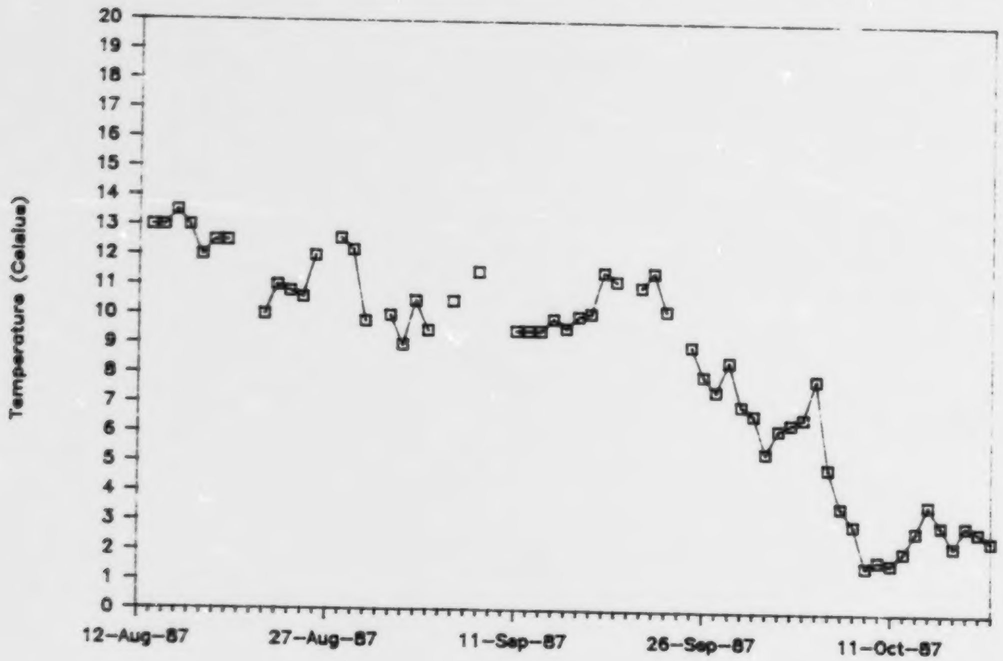


Figure 18: Trout biomass sampled in the 12-Mile Creek fish fence.



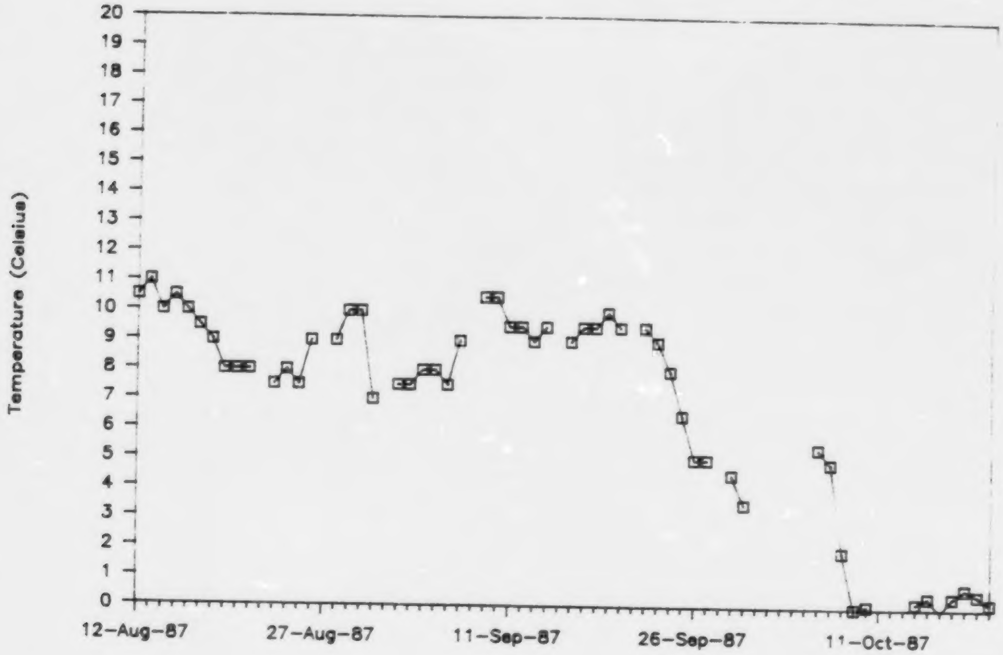
Wilson Creek a.m. temperature data.



Wilson Creek p.m. temperature data.

Figure 19: Temperature data for the Wilson Creek fish fence.

9–Mile Creek a.m. temperature data.



9–Mile Creek p.m. temperature data.

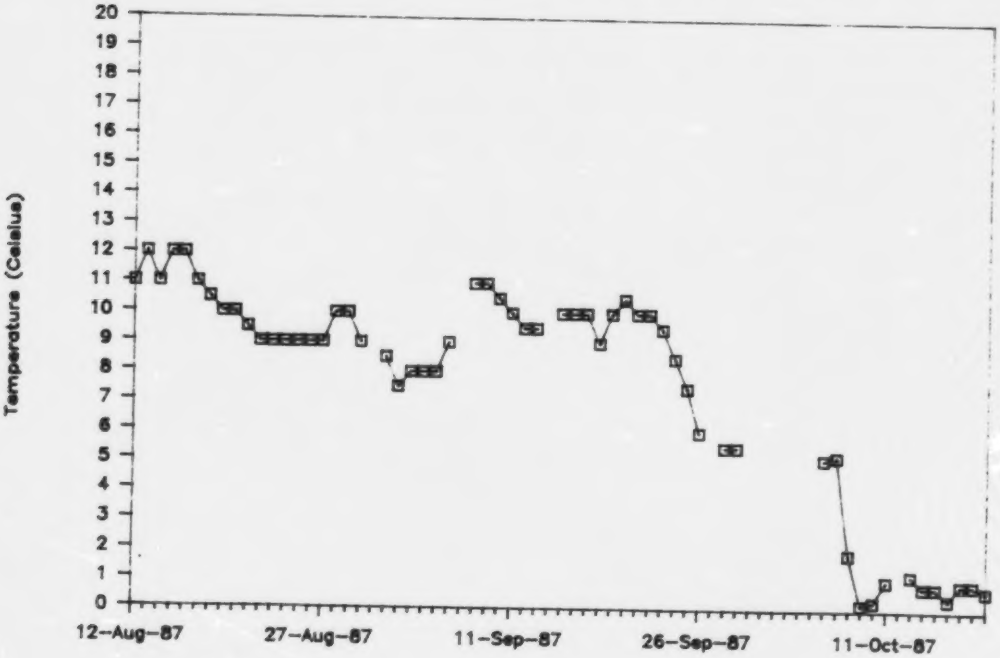
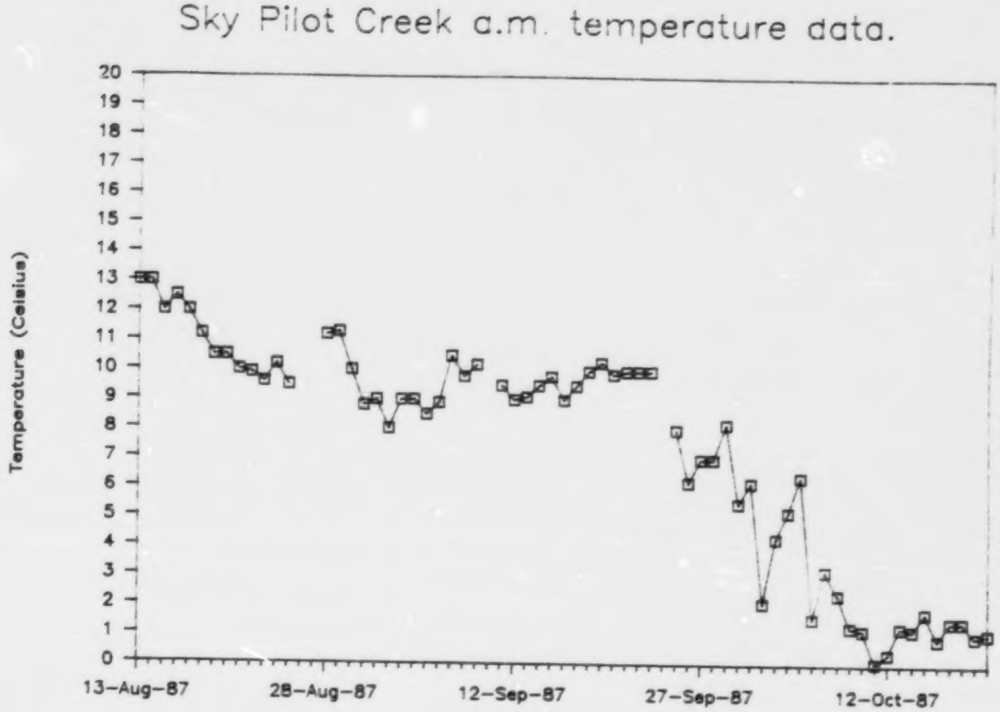


Figure 20: Temperature data for the 9-Mile Creek fish fence.



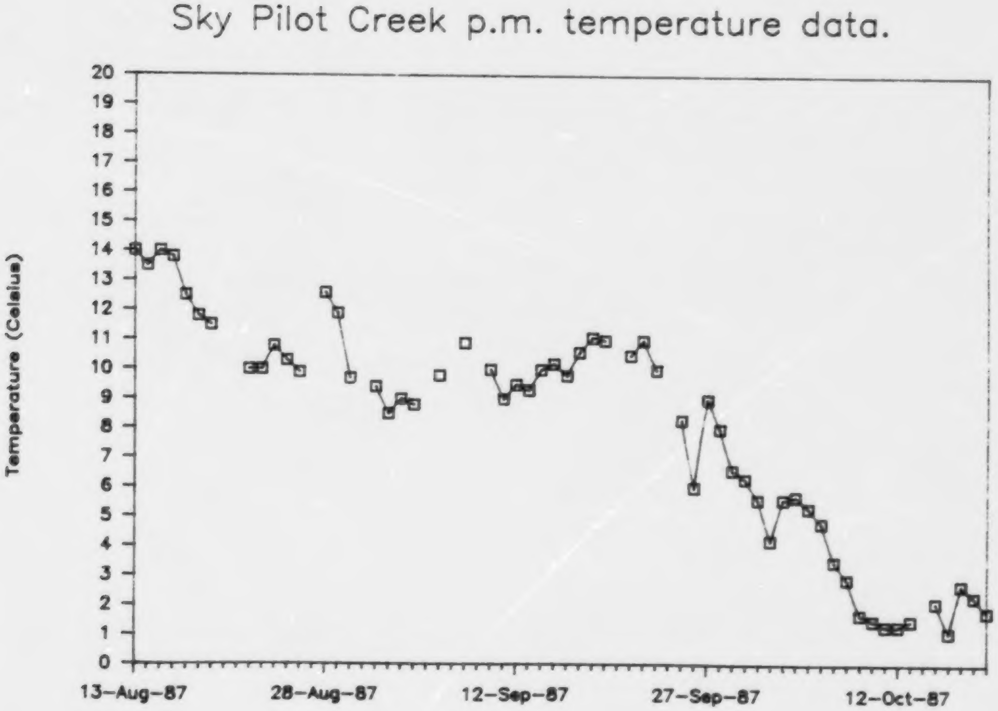


Figure 21: Temperature data for the Sky Pilot Creek fish fence.

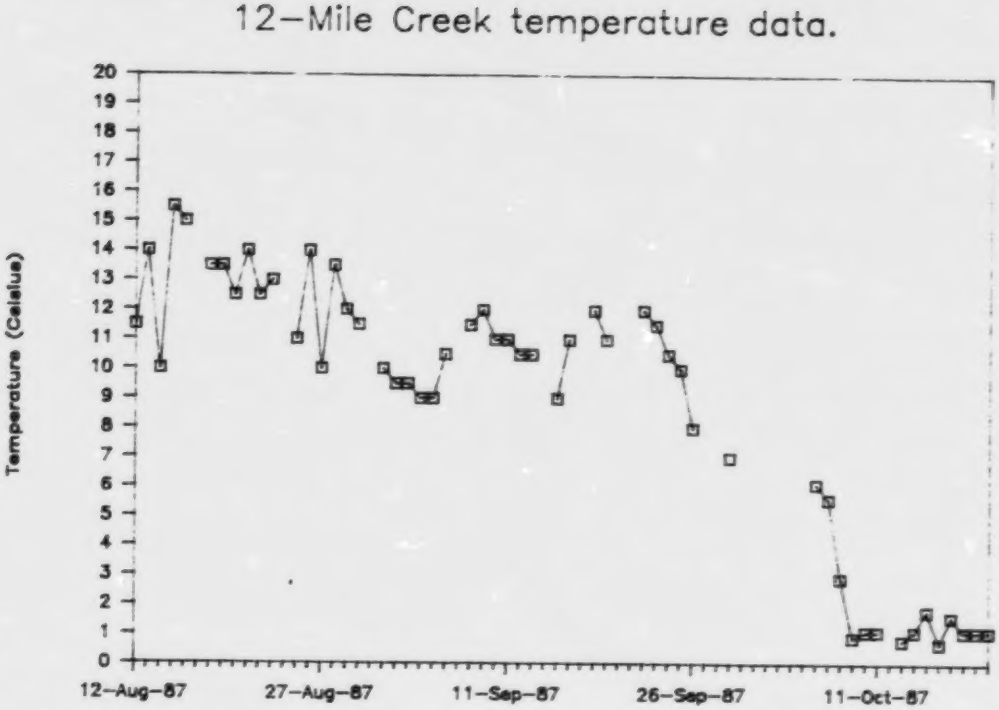
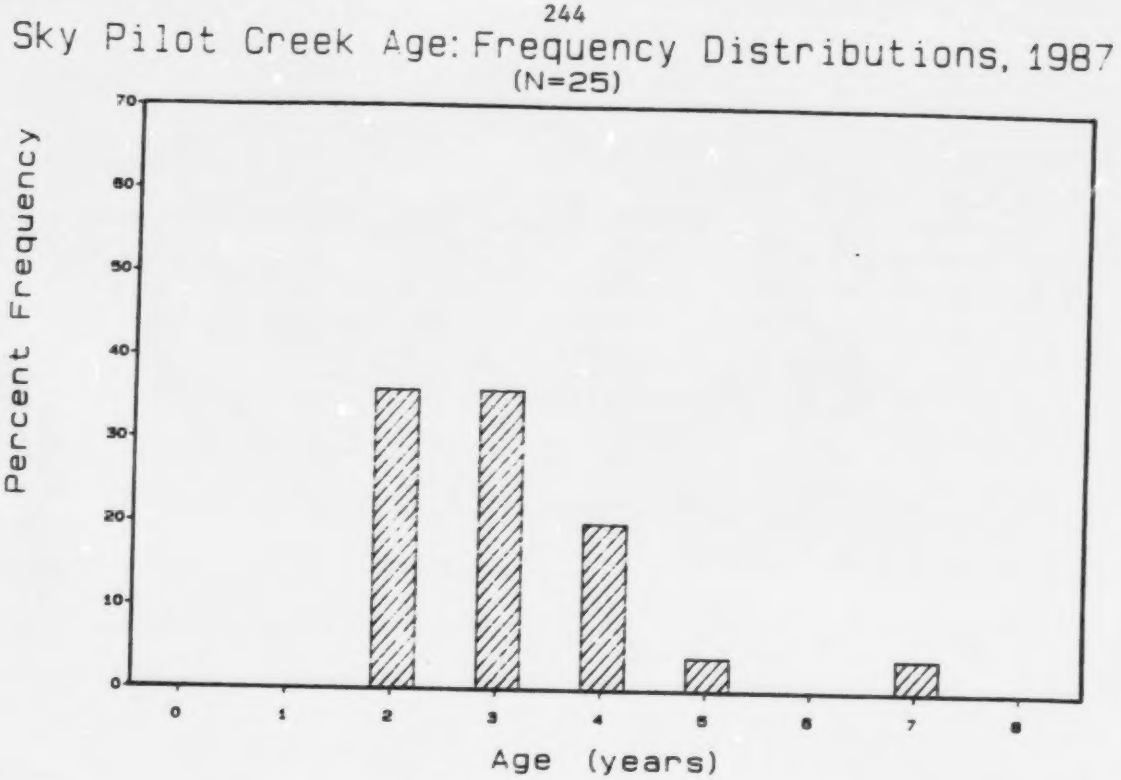


Figure 22: Temperature data for the 12-Mile Creek fish fence.

Age:frequency distributions are presented in Figures 23 and 24. As can be seen, most trout sampled were young; 3+ years or younger. Likewise length:frequency distributions were skewed to the small end of the scale (Figures 25 and 26). Likewise the biomass sampled was also low (Figures 15-18).

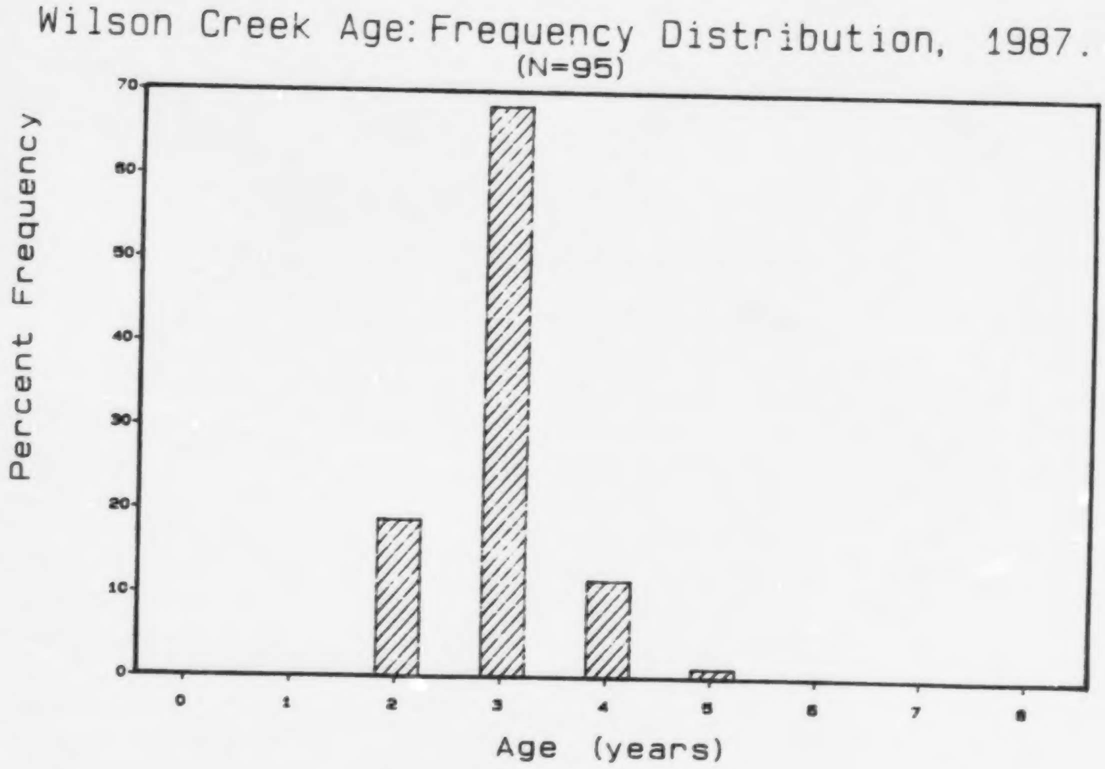
Based on this years data, it is felt that monitoring the fences in September and October in 1988 will provide the information required. Moreover, because most trout were sampled in the evening having moved downstream during the day, sampling will be done only in the late afternoon with periodic checks to ensure that trout are not overcrowding in fence traps until maintenance requirements are such that twice daily cleaning is required.

It should be stressed that the data for trout sampled in these fences does not necessarily reflect the total spawning population. Rather they are intended to reflect relative levels of trout abundance and biomass which can be monitored over the course of construction, impoundment and operation of the Limestone Generating Station. The use of tag recapture data may in fact provide population abundance estimates if enough trout are sampled.



Sky Pilot Creek Age: Frequency Distributions, 1987

(N=25)



Wilson Creek Age: Frequency Distribution, 1987.

(N=95)

Figure 23: Age:frequency distribution for Sky Pilot and Wilson Creeks fish fence data.

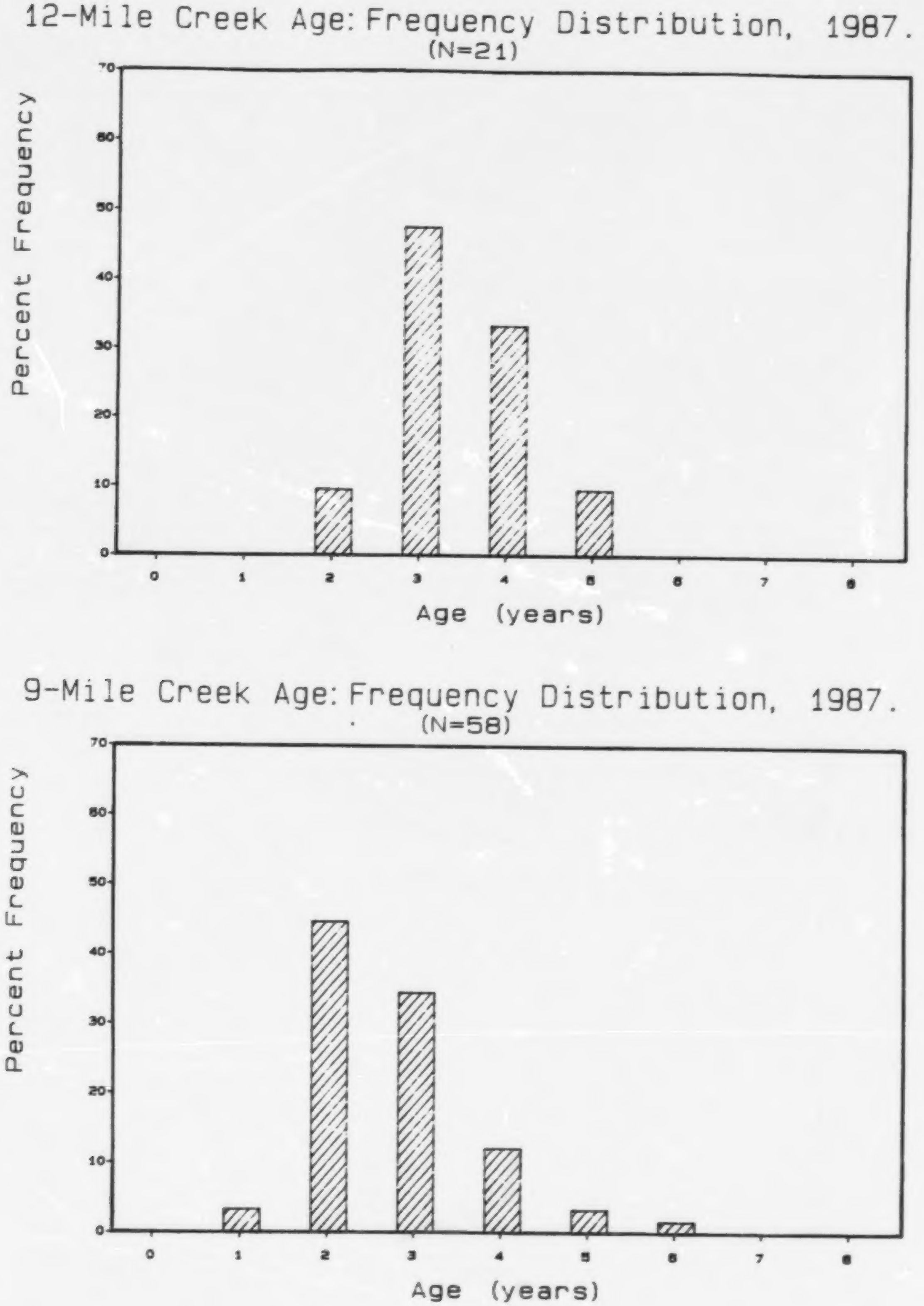


Figure 24: Age:frequency distributions for 12-Mile and 9-Mile Creeks fish fence data.

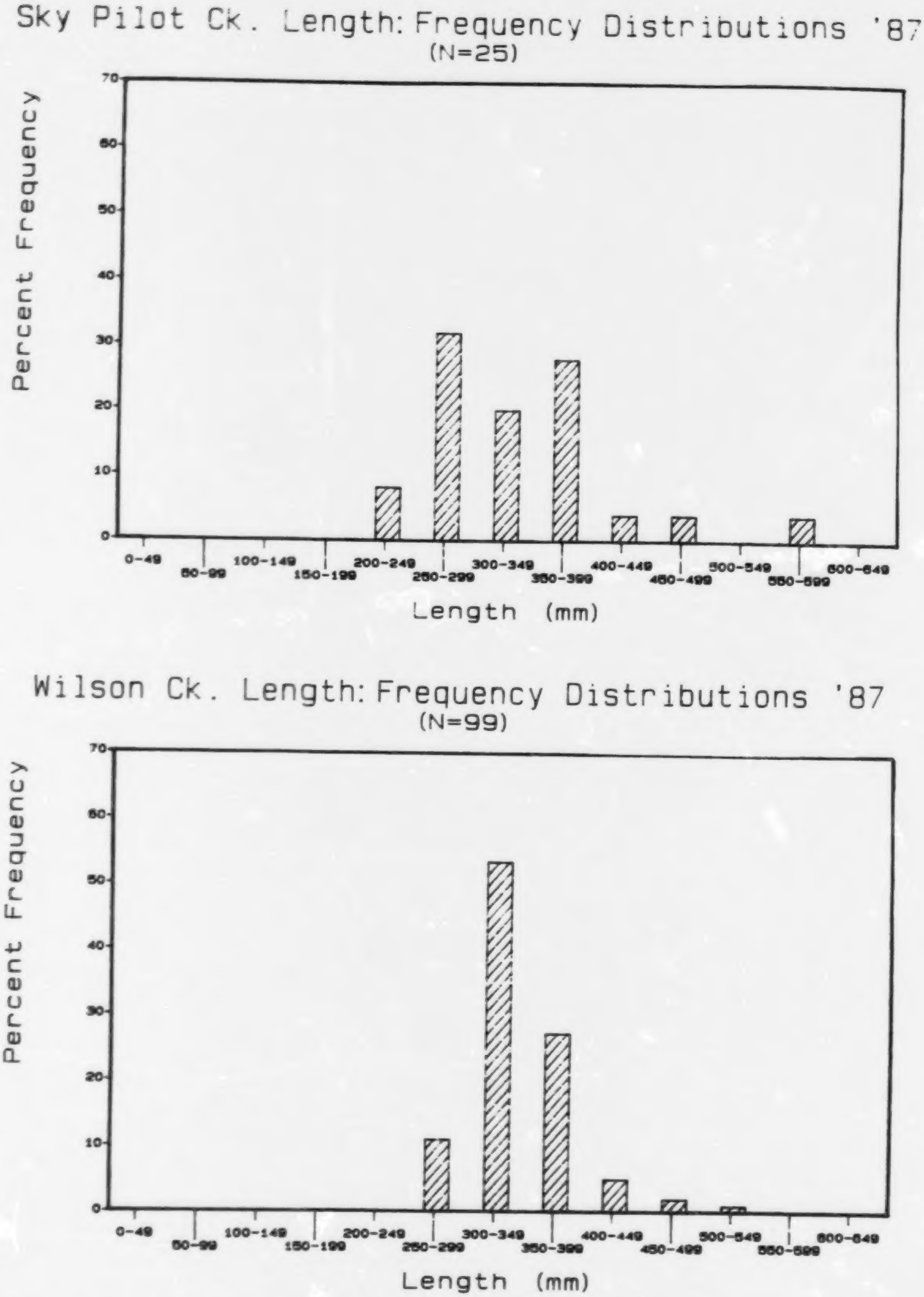
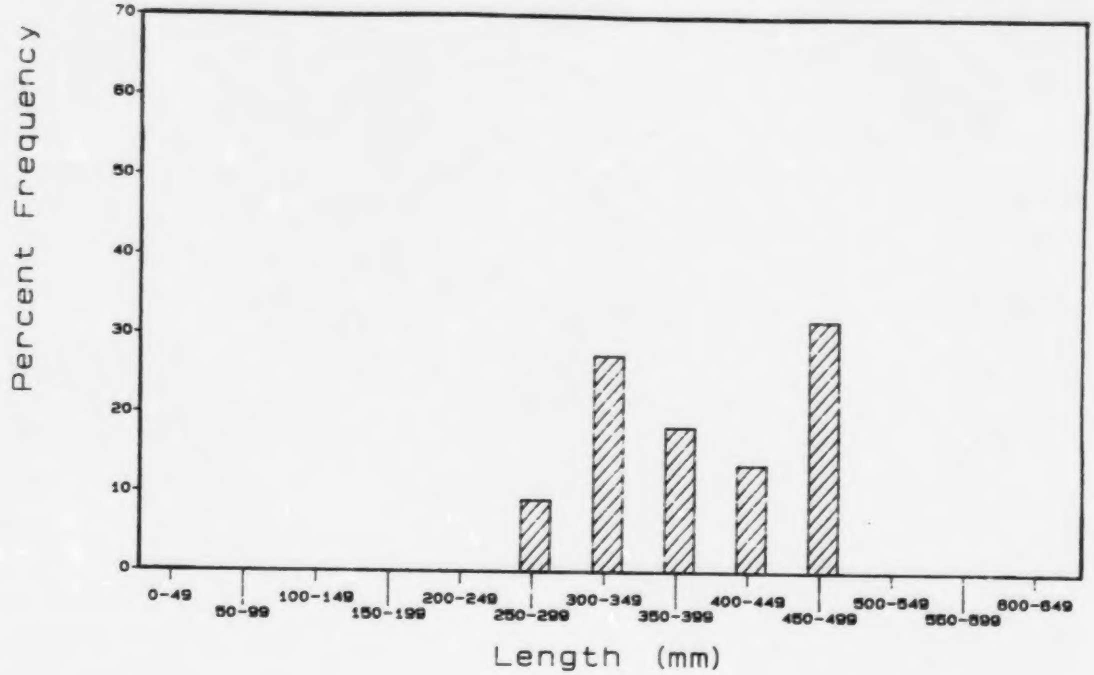


Figure 25: Length:frequency distributions for Sky Pilot and Wilson Creeks fish fence data.

12-Mile Ck. Length: Frequency Distributions '87
(N=22)



9-Mile Ck. Length: Frequency Distributions '87
(N=66)

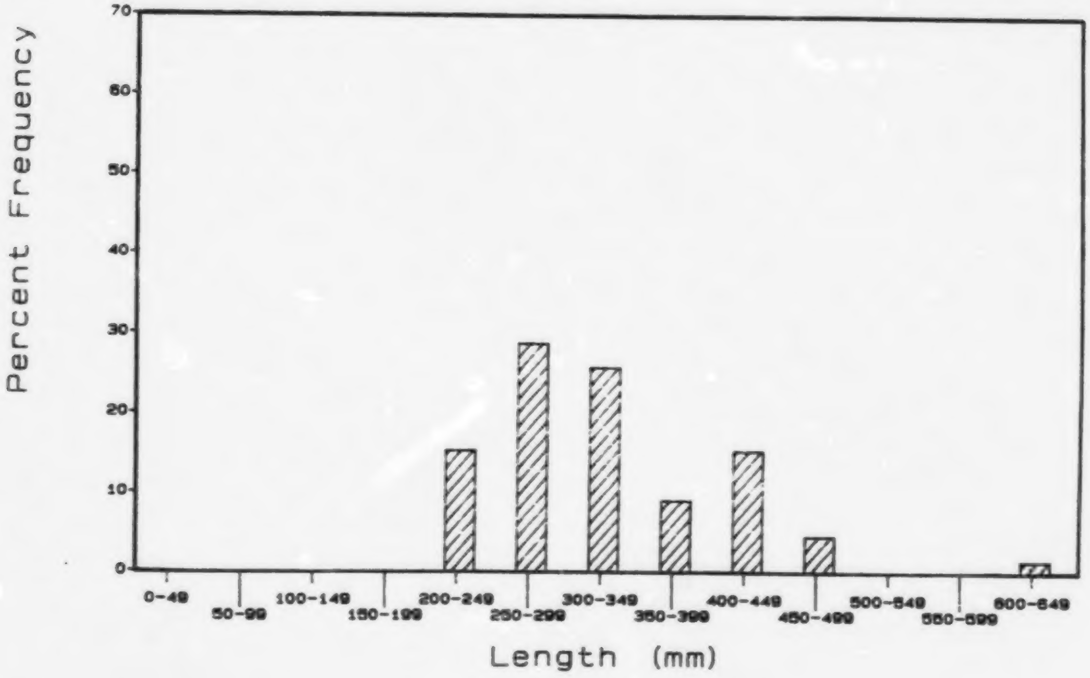


Figure 26: Length:frequency distributions for 12-Mile and 9-Mile Creeks fish fence data.

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Appendix 1: Mean fork length of brook trout sampled in the lower Nelson River watershed in 1948-50 and 1975-78 (Gaboury 1978; unpublished information) and in 1985-87 (Swanson 1986; Swanson and Kansas 1987; unpublished information).

Stream	Mean Length of Brook Trout Sampled (combined sexes)			
	1948-50	1975-77	1985	1987
Wilson Ck.		370.7(7)	339.9(9)	340.8(98)
Sky Pilot Ck.	403.49(145)	371.4(236)	335.2(94)	339.8(34)
12-Mile Ck.		433.8(31)	467.0(5)	389.4(22)
9-Mile Ck.		394.2(265)	362.4(23)	324.1(66)
Limestone R.		467.6(75)	500.6(19)[a]	
Weir R.		468.8(120)[b]	471.1(29)[c]	

[a] contains 1985 and 1986 brook trout sampled at 5-Mile Hole (Swanson and Kansas 1987)

[b] contains 1978 Weir River spawning pool samples (Gaboury, unpublished information)

[c] contains 1986 Weir River spawning pool samples (Swanson and Kansas 1987)

APPENDIX 2

Stage : discharge relationships for Beaver, CN and Moondance Creeks

Stage data indicated significant relationships to measured discharge for Beaver, CN and Moondance Creeks. The regression statistics are presented in Appendix 2A and a plot of the stage : discharge relationships are given in Appendix 2B.

A

```
UNWEIGHTED LEAST SQUARES LINEAR REGRESSION FOR LST

PREDICTOR
VARIABLES     COEFFICIENT   STD ERROR    STUDENT S T      P
----------   -----------   ----------   -----------   ------
CONSTANT      -7.927E-02    1.720E-02      -4.61      0.0440
LD             6.694E-02    1.100E-02       6.09      0.0260

CASES INCLUDED              4      MISSING CASES    0
DEGREES OF FREEDOM          2
OVERALL F               37.09      P VALUE      0.0260
ADJUSTED R SQUARED     0.9231
R SQUARED              0.9488
MEAN SQUARED ERROR   3.190E-04


      ST            Q            LST          LD          PRED
 1  7.8000E-01  2.1300E-01 -1.0791E-01 -6.7162E-01 -1.2423E-01
 2  7.7500E-01  1.7000E-01 -1.1071E-01 -7.6955E-01 -1.3078E-01
 3  6.6300E-01  6.2000E-02  1.7849E-01 -1.2076     -1.6010E-01
 4  5.5600E-01  2.0000E-03 -2.5493E-01 -2.6990     -2.5993E-01
```

B

```
UNWEIGHTED LEAST SQUARES LINEAR REGRESSION FOR LST

PREDICTOR
VARIABLES     COEFFICIENT   STD ERROR    STUDENT S T      P
----------   -----------   ----------   -----------   ------
CONSTANT      -5.958E-04    1.076E-02      -0.06      0.9594
LD             1.027E-01    1.303E-02       7.88      0.0157

CASES INCLUDED              4      MISSING CASES    0
DEGREES OF FREEDOM          2
OVERALL F                62.1      P VALUE      0.0158
ADJUSTED R SQUARED     0.9532
R SQUARED              0.9688
MEAN SQUARED ERROR   1.670E-04


      ST            Q            LST          LD          PRED
 1  0.9530      5.5700E-01 -2.0907E-02 -2.5414E-01 -2.6701E-02
 2  9.4800E-01  5.1400E-01 -2.3192E-02 -2.8904E-01 -3.0285E-02
 3  8.6000E-01  3.3100E-01 -6.5502E-02 -4.8017E-01 -4.9918E-02
 4  7.1000E-01  3.4000E-02 -1.4874E-01 -1.4685     -1.5144E-01
```

C

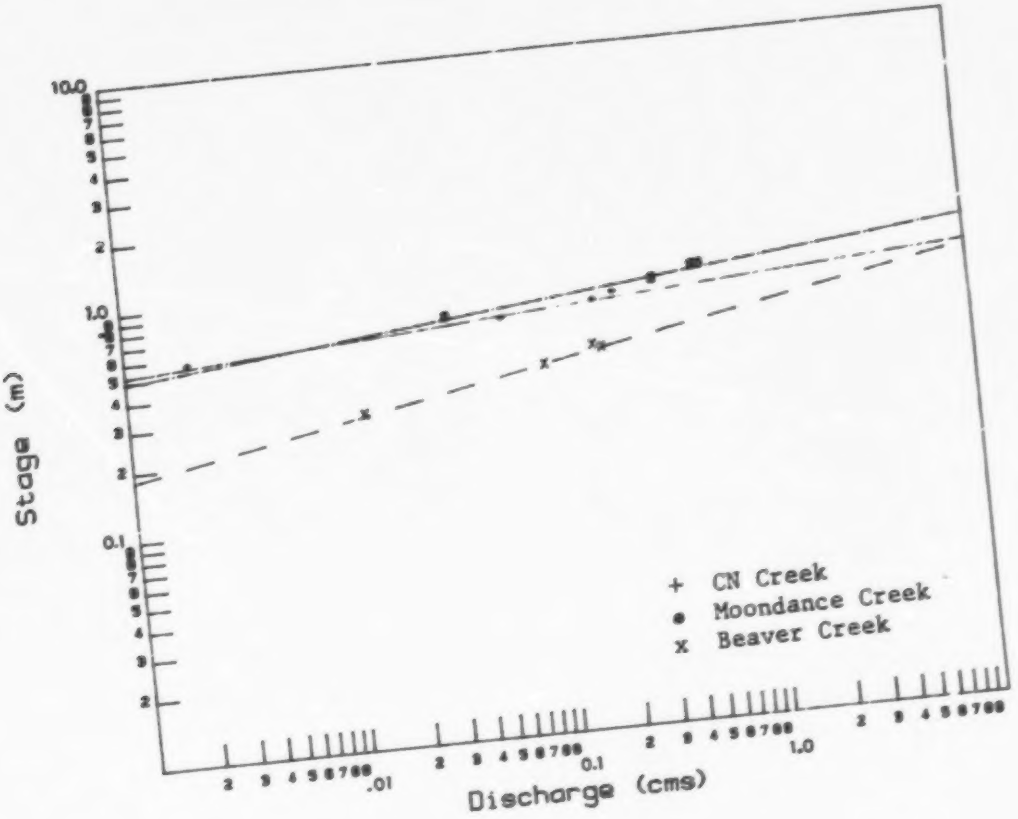
```
UNWEIGHTED LEAST SQUARES LINEAR REGRESSION FOR LST

PREDICTOR
VARIABLES     COEFFICIENT   STD ERROR    STUDENT S T      P
----------   -----------   ----------   -----------   ------
CONSTANT      -2.070E-01    1.721E-02     -12.03      0.0068
LD             1.778E-01    1.432E-02      12.42      0.0064

CASES INCLUDED              4      MISSING CASES    0
DEGREES OF FREEDOM          2
OVERALL F               154.3      P VALUE      0.0064
ADJUSTED R SQUARED     0.9808
R SQUARED              0.9872
MEAN SQUARED ERROR   1.732E-04


      ST            Q            LST          LD          PRED
 1  4.6500E-01  1.6300E-01 -3.3255E-01 -7.8781E-01 -3.4704E-01
 2  4.5000E-01  1.7900E-01 -3.4679E-01 -7.4715E-01 -3.3980E-01
 3  4.0000E-01  9.5000E-02 -3.9794E-01 -1.0223     -3.8873E-01
 4  2.8800E-01  1.3000E-02 -5.4061E-01 -1.8861     -5.4232E-01
```

Appendix 2A: Regression statistics calculated for stage : discharge relationships for : CN Creek (A) Moondance Creek (B) and Beaver Creek (C) in 1987.



Appendix 2B: Stage : discharge relationships for the study streams in 1987.

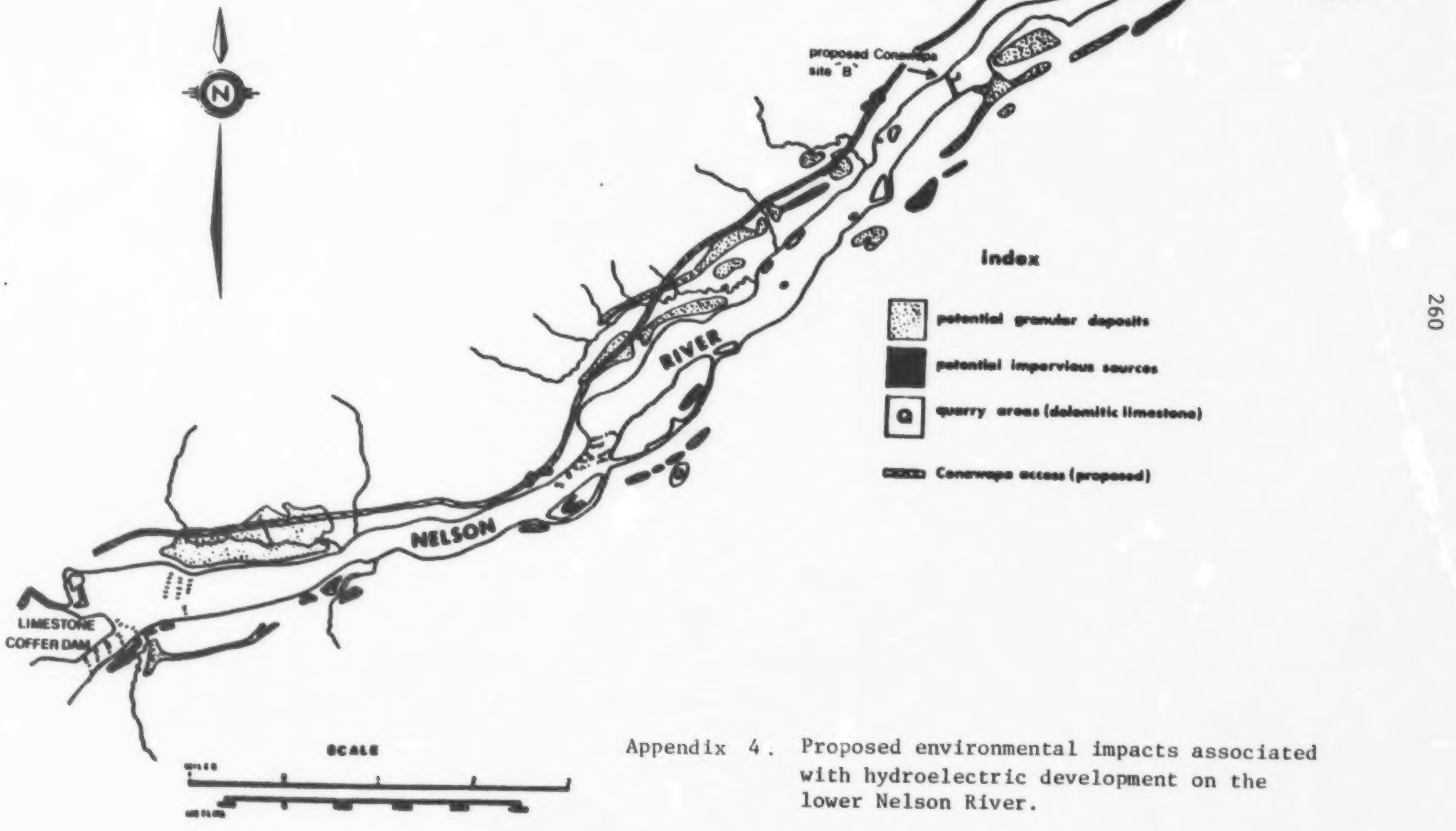
Appendix 3: FLIR data.

Geographic Area	Creek	Contour Internal (m)	Length of Contour Internal (Km)	Number of Upwellings Identified	Number of Upwellings per Km
Limestone Forebay					
	Wilson	84-90	2.598	23	8.9
		90-100	5.312	35	6.6
		100-110	5.237	45	8.6
		110-120	5.000	43	8.6
	Sky Pilot	84-90	1.380	7	5.1
		90-100	3.021	10	3.3
		100-114.3	13.252*	7	0.5
	Leslie	76-80	.424	2	4.7
		80-90	1.295	1	0.8
		90-100	3.636	5	1.4
	Brooks	74-80	1.831	10	5.5
Limestone River					
	9-Mile	81-84	.151	0	0
		84-91	6.086	28	4.6
		91-99	.829*	1	1.2
	12-Mile	85-91	4.200	37	8.8
		91-99	5.454	29	5.3
		99-107	9.921*	13	1.3
Limestone River					
	McMillan	87-91	3.852	22	5.7
		91-99	15.225	69	4.5
		99-107	5.156	2	0.4
		107-114	10.073	6	0.6
Downstream Tributaries					
	Moondance	53-61	.290	0	0
		61-69	.749	6	8.0
		69-76	.879	12	13.7
		76-90	1.151*	9	7.8
	Swift	36-40	.480+	0	0
		40-50	1.110+	0	0
		50-60	1.069	3	5.6
		60-70	1.199	8	6.7
		70-80	1.277	5	3.9
		80-90	.694*	2	2.8
	Goose	34-40	.384	1	2.6
		40-50	.543	4	7.4
		50-60	.402	3	7.5
		60-70	.566	5	8.8
		70-80	.407*	4	9.8
Downstream Tributaries					
	Anyways	25-30	.355	0	0
		30-40	.635	0	0
		40-50	.590	3	5.1
		50-60	1.073	2	1.9
		60-70	.515	5	9.7
		70-80	.521	2	3.8

* the entire contour interval was not surveyed.

+ stream habitat in contour interval was dry.

x half of the contour interval consisted of dry streambed.


proposed Conawapa site "DX"
proposed Conawapa site "B"
NELSON
RIVER
LIMESTONE COFFER DAM
Index
potential granular deposits
potential impervious sources
Q
quarry areas (dolomitic limestone)
Conawapa access (proposed)
SCALE

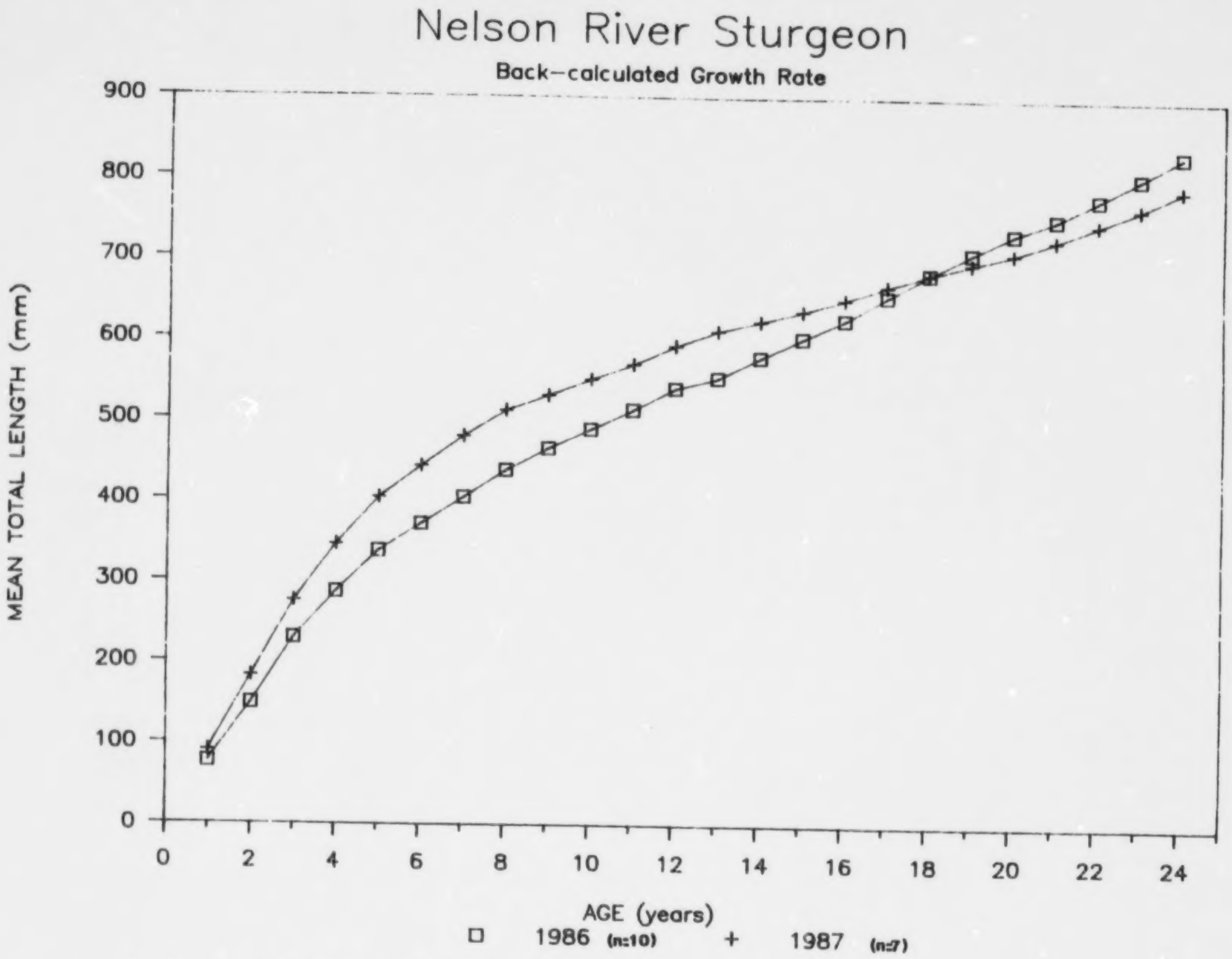
Appendix 4. Proposed environmental impacts associated with hydroelectric development on the lower Nelson River.

Appendix 5. Catch and release information and sturgeon transferred to the Long Spruce Reservoir.

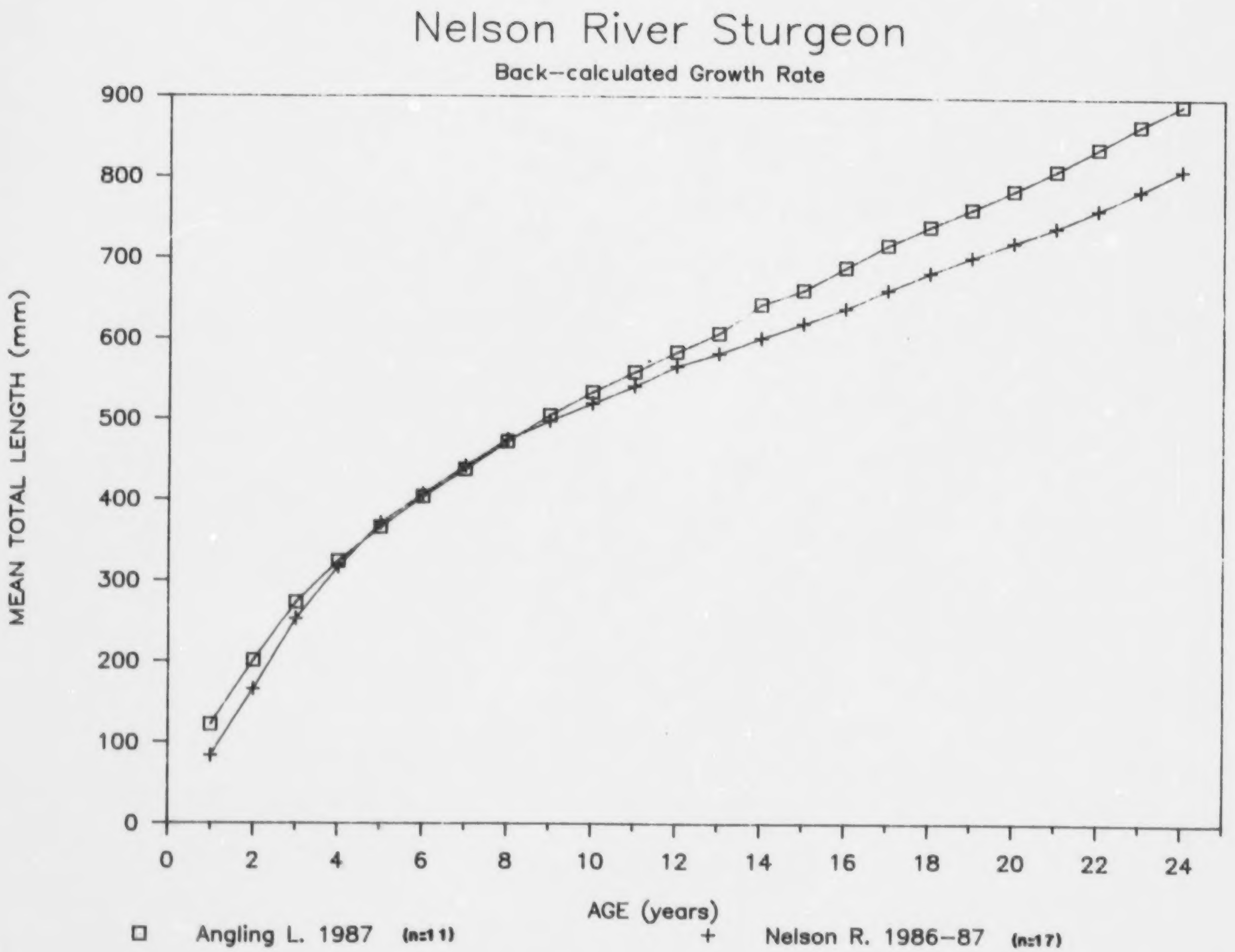
Date	Capture Site	Release Site	Total Weight		Transmitter Information			Comments
			Length(mm)	(g)	weight(g)	duration(years)	freq.(Mhz)	
01 07 87	Nelson R. (5 Km down from Angling R.)	mouth of Kettle R.	1100	8165	45	1	48.161	in rough shape upon release
01 07 87	Nelson R., downstream side of Deer Is.	mouth of Kettle R.	1205	10886	90	3	48.240	chewed up tail
12 07 87	Angling Lake	below CN bridge	1200	9979	45	1	48.179	in good shape
12 07 87	Angling Lake	below CN bridge	1275	11340	90	3	48.302	in good shape
12 07 87	Angling lake	mouth of Boots Creek	1330	14152	90	3	48.218	in good shape
12 07 87	Angling Lake	mouth of Boots Creek	1415	19958	45	1	48.125	in good shape

Appendix 6. Tagging data for lower Nelson River sturgeon in 1987.

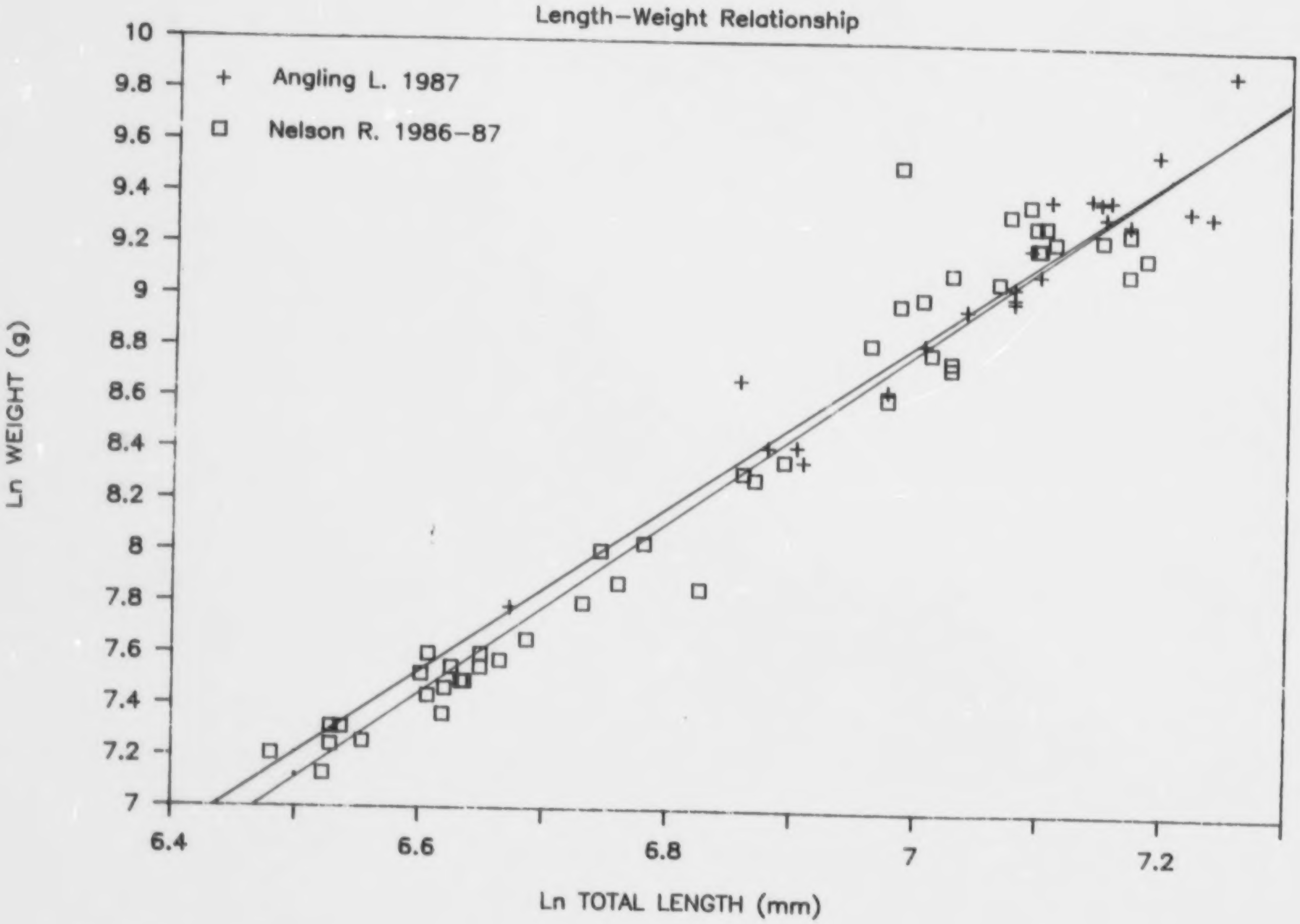
Date	Location	Set #	Total length (mm)	Weight (gm)	Age	Floy Tag #	Disc Tag #
20 06 87	mouth of Weir R.	1	880	3100	25	OR00750	0076
20 06 87	mouth of Weir R.	1	801	2120	32	OR00749	0077
20 06 87	mouth of Weir R.	1	754	1900	25	OR00748	0078
20 06 87	mouth of Weir R.	1	838	2450	25	OR00747	0079
20 06 87	@ proposed DX axis site	2	862	2650	27	OR00745/46	0080
20 06 87	@ proposed DX axis site	2	736	1850	18	OR00744	0081
20 06 87	@ proposed DX axis site	2	750	1750	21	OR00743	0082
20 06 87	@ proposed DX axis site	2	684	1500	21	OR00742	0083
20 06 87	@ proposed DX axis site	2	702	1420	19	OR00741	0084
20 06 87	@ proposed DX axis site	2	772	2000	23	OR00740	0085
20 06 87	@ proposed DX axis site	2	680	1250	15	OR00739	0086
20 06 87	@ proposed DX axis site	2	760	1800	23	OR00738	0087
20 06 87	1 Km downstream from DX	4	690	1500	18	OR00734	0088
20 06 87	5 Km downstream from Angling R.	5	652	1350	23	OR00733	0089
26 06 87	5 Km downstream from Angling R.	5	762	1800	23	OR00726	0090
29 06 87	downstream tip of Deer Island	6	962	4000	25	OR00701	0100



Appendix 7: Nelson River 1986 vs. 1987 back calculated growth rate to age 24 for lake sturgeon.



Appendix 8: Comparison of Angling Lake 1987 vs. Nelson River 1986-87 back-calculated growth rate to age 24 for lake sturgeon.



Appendix 9: Comparison of length-weight relationship for Angling Lake and Nelson River lake sturgeon.

Appendix 10: Experimental gillnet catch data (frequency) for standard gangs set in Angling Lake in 1987.

Set	L. Whitefish	Walleye	Y. Perch	N. Pike	L. Cisco	W. Sucker	L. Sturgeon
1	12	10	5	11	0	15	0
2	14	13	0	11	1	10	0
3	3	7	3	4	2	23	2
4	5	4	0	2	12	5	0
5	8	13	8	14	0	21	0
6	4	7	4	10	1	3	1
7	4	3	2	23	0	0	0
8	5	3	15	25	0	19	5
9	2	8	0	5	3	11	0
10	1	6	6	7	0	7	0
11	1	3	10	6	1	9	1
12	6	14	0	16	0	6	0
Total	65	91	53	134	20	129	9
CPUE	5.42	7.58	4.42	11.17	1.67	10.75	0.75
% Comp.	13.0	18.2	10.6	26.7	4.0	25.7	1.8

TOTAL NUMBER = 501
TOTAL CPUE = 41.75/std. gang/night

Appendix 11: **Experimental** gillnet catch data (weight in kg) for standard gangs set in Angling Lake in 1987.

Set	L. Whitefish	Walleye	Y. Perch	N. Pike	L. Cisco	W. Sucker	L. Sturgeon
1	9.190	8.430	0.105	28.595	0	15.800	0
2	10.525	10.240	0	14.120	0.040	14.380	0
3	1.670	4.000	0.120	17.600	0.220	25.770	21.266
4	3.870	2.140	0	5.790	1.100	4.410	0
5	5.690	6.350	0.160	33.490	0	22.250	0
6	3.340	7.300	0.080	23.310	0.100	4.590	2.410
7	1.110	1.710	0.080	47.550	0	0	0
8	2.590	1.340	0.530	87.440	0	25.230	27.910
9	2.300	6.950	0	12.700	0.260	9.230	0
10	1.340	4.670	0.150	21.160	0	9.070	0
11	0.750	2.950	0.400	16.450	0.030	8.580	2.300
12	6.070	15.140	0	28.580	0	6.840	0
Total	48.445	71.220	1.625	336.785	1.750	146.150	53.886
CPUE	4.037	5.935	0.135	28.065	0.146	12.179	4.491
% Comp.	7.3	10.8	0.2	51.0	0.3	22.1	8.2

TOTAL WEIGHT = 659.861 kg
TOTAL CPUE = 54.988 kg/std. gang/night

Appendix 12: Summary of lake sturgeon sampled in Angling Lake in 1987.

Date	Set	Mesh Size (cm)	Sample #	FL (mm)	TL (mm)	Weight (G)	Age	Comments
04-July-87	3	12.70	145	1105	1210	9050	40	Released
04-July-87	3	12.70	146	1185	1260	12216	39	Released
05-July-87	6	9.53	203	708	790	2410	20	Released
06-July-87	8	12.70	301	860	950	5900	31	Released
07-July-87	8	12.70	302	905	995	4560	30	Released
07-July-87	8	10.80	306	1072	1185	8600	46	Released
07-July-87	8	10.80	307	912	1000	4300	31	Released
07-July-87	8	9.53	316	864	972	4550	23	Released
10-July-87	11	10.80	458	730	785	2330		Recapture (203 ?)
04-July-87	1	22.86	1 *	1169	1300	11080	50	Released
04-July-87	1	22.86	2 *	1175	1280	12159	41	Released
04-July-87	1	22.86	3 *	1040	1140	7850	32	Released
04-July-87	1	22.86	4 *	1150	1220	12102	41	Released
04-July-87	1	22.86	5 *	950	1070	5700	24	Released
04-July-87	1	22.86	6 *	1145	1270	12045	49	Released
04-July-87	1	22.86	7 *	1230	1365	11705	39	Released
10-July-87	2	22.86	8 *	1070	1185	8120	39	Released
10-July-87	2	22.86	9 *	980	1102	6840	31	Released
10-July-87	2	22.86	10 *	1260	1390	11477	49	Released
10-July-87	2	22.86	11 *	1100	1185	8250	34	Released
10-July-87	2	22.86	48.179 *	1110	1200	10000		Transf. to L.S.Res.
10-July-87	2	22.86	48.302 *	1190	1275	11364		Transf. to L.S.Res.
10-July-87	2	22.86	48.218 *	1250	1330	14545		Transf. to L.S.Res.
10-July-87	2	22.86	48.124 *	1335	1415	20000		Transf. to L.S.Res.

* denotes sturgeon captured in 22.86 cm mesh (9"), separate from standard gangs

Appendix 13: Summary of yellow perch from which aging structures were taken sampled in Angling Lake in 1987.

Date	Sample #	Mesh Size (cm)	Fork Length (mm)	Weight (gm)	Age
06-July-87	298	3.8	142	40	3
06-July-87	299	3.8	144	40	4
06-July-87	353	5.1	195	110	7
06-July-87	358	3.8	147	30	3
06-July-87	359	3.8	139	30	4
06-July-87	360	3.8	150	30	5
06-July-87	361	3.8	132	30	4
06-July-87	362	3.8	144	30	4
06-July-87	363	3.8	128	30	4
06-July-87	364	3.8	126	30	4
06-July-87	365	3.8	134	30	4
06-July-87	366	3.8	130	30	3
06-July-87	367	3.8	130	30	4
06-July-87	368	3.8	128	30	4
06-July-87	369	3.8	132	30	4
06-July-87	370	3.8	140	30	4
06-July-87	371	3.8	141	30	4
09-July-87	372	3.8	145	25	4
09-July-87	373	3.8	141	25	4
09-July-87	374	3.8	138	25	4
09-July-87	375	3.8	142	25	4
09-July-87	376	3.8	138	25	4
09-July-87	377	3.8	142	25	4

APPENDIX 14

Mesh size effects on walleye, whitefish and northern pike in Angling Lake in 1987

```
                     1.5 inch Angling Lake Mesh Size Effects Whitefish

                                                                       Frequency mature fish
                                                                       ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight     S.E.(W)      Male     Female
--------------------------------------------------------------------------------------------

 0      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 1      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 2      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 3      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 4      2     33.33      290.00       19.00      280.00         30.00        0.00      0.00
 5      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 6      1     16.67      373.00        0.00     1780.00          0.00        0.00    100.00
 7      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 8      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 9      3     50.00      377.33        5.70      693.33         61.73      100.00    100.00
--------------------------------------------------------------------------------------------

Total no. fish=  6
Total weight of all fish=  2640
Overall mean length=  346.7778  S.E.=  28.41636
Overall mean weight=  917.7778  S.E.=  447.3185
No. immature males=  1  No. mature males=  2
No. immature females=  1  No. mature females=  2
Immature sex ratio=  1  females/male
Mature sex ratio=  1  females/male
Overall sex ratio=  1  females/male

summary data on file  9
```

```
                       2 inch Angling Lake Mesh Size Effects Whitefish

                                                                        Frequency mature fish
                                                                        ---------------------
Age    No.   Freq.(%)  Mean length    S.E.(L)   Mean weight    S.E.(W)      Male    Female
-------------------------------------------------------------------------------------------

 0      0      0.00       0.00         0.00         0.00         0.00       0.00     0.00
 1      0      0.00       0.00         0.00         0.00         0.00       0.00     0.00
 2      0      0.00       0.00         0.00         0.00         0.00       0.00     0.00
 3      5     35.71     256.80         5.34       210.00        15.08       0.00     0.00
 4      4     28.57     274.75        16.94       280.00        66.96       0.00     0.00
 5      1      7.14     283.00         0.00       290.00         0.00       0.00     0.00
 6      4     28.57     322.25        21.81       470.00       142.30      33.33   100.00
-------------------------------------------------------------------------------------------

Total no. fish=  14
Total weight of all fish=  4050
Overall mean length=  284.2  S.E.=  175.0949
Overall mean weight=  312.5  S.E.=  560.0883
No. immature males=  10  No. mature males=  1
No. immature females=  2  No. mature females=  1
Immature sex ratio=  .2  females/male
Mature sex ratio=  1  females/male
Overall sex ratio=  .2727273  females/male

summary data on file  10
```

```
                    3 inch Angling Lake Mesh Size Effects Whitefish

                                                                           Frequency mature fish
Age   No.   Freq.(%)  Mean length   S.E.(L)   Mean weight     S.E.(W)     --------------------
                                                                              Male     Female
---------------------------------------------------------------------------------------------
 0     0      0.00        0.00        0.00         0.00         0.00         0.00       0.00
 1     0      0.00        0.00        0.00         0.00         0.00         0.00       0.00
 2     0      0.00        0.00        0.00         0.00         0.00         0.00       0.00
 3     0      0.00        0.00        0.00         0.00         0.00         0.00       0.00
 4     5     33.33      313.60        7.75       422.00        41.16         0.00      33.33
 5     1      6.67      320.00        0.00       420.00         0.00         0.00       0.00
 6     5     33.33      341.80       14.11       526.00        82.74       100.00       0.00
 7     0      0.00        0.00        0.00         0.00         0.00         0.00       0.00
 8     1      6.67      413.00        0.00      1000.00         0.00         0.00       0.00
 9     0      0.00        0.00        0.00         0.00         0.00       100.00       0.00
10     2     13.33      442.50        5.50      1270.00        70.00         0.00       0.00
11     0      0.00        0.00        0.00         0.00         0.00       100.00     100.00
12     1      6.67      434.00        0.00      1040.00         0.00         0.00       0.00
                                                                           100.00       0.00
---------------------------------------------------------------------------------------------

Total no. fish=  15
Total weight of all fish=  7280
Overall mean length=  377.4833  S.E.=  153.6575
Overall mean weight=  779.6667  S.E.=  401.3889
No. immature males=  3  No. mature males=  5
No. immature females=  5  No. mature females=  2
Immature sex ratio=  1.666667  females/male
Mature sex ratio=  .4  females/male
Overall sex ratio=  .875  females/male

summary data on file  11
```

```
                     3.75 inch Angling Lake Mesh Size Effects Whitefish

                                                                      Frequency mature fish
                                                                      ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight    S.E.(W)       Male    Female
--------------------------------------------------------------------------------------------
 0      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
 1      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
 2      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
 3      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
 4      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
 5      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
 6      2    12.50     356.00         6.00      595.00          5.00      100.00    100.00
 7      9    56.25     387.33        13.54      918.89        136.30       50.00    100.00
 8      1     6.25     402.00         0.00      940.00          0.00        0.00    100.00
 9      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
10      2    12.50     429.00        41.00     1260.00        440.00      100.00    100.00
11      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
12      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
13      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
14      1     6.25     406.00         0.00      950.00          0.00        0.00    100.00
15      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
16      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
17      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
18      0     0.00       0.00         0.00        0.00          0.00        0.00      0.00
19      1     6.25     492.00         0.00     1920.00          0.00        0.00    100.00
--------------------------------------------------------------------------------------------

Total no. fish=  16
Total weight of all fish=  11980
Overall mean length=  412.0556  S.E.=  229.0451
Overall mean weight=  1097.315  S.E.=  563.1623
No. immature males=  2  No. mature males=  4
No. immature females=  0  No. mature females=  10
Immature sex ratio=  0  females/male
Mature sex ratio=  2.5  females/male
Overall sex ratio=  1.666667  females/male

summary data on file  12
```

4.25 inch Angling Lake Mesh Size Effects Whitefish

Age	No.	Freq.(%)	Mean length	S.E.(L)	Mean weight	S.E.(W)	Frequency mature fish	
							Male	Female
0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	2	28.57	382.00	6.00	800.00	50.00	100.00	100.00
7	2	28.57	392.00	10.00	832.50	92.50	0.00	100.00
8	1	14.29	407.00	0.00	960.00	0.00	100.00	0.00
9	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1	14.29	444.00	0.00	1100.00	0.00	100.00	0.00
14	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1	14.29	463.00	0.00	1480.00	0.00	100.00	0.00

```
Total no. fish=  7
Total weight of all fish=  3265
Overall mean length=  417.6  S.E.=  360.3736
Overall mean weight=  1034.5  S.E.=  923.1266
No. immature males=  0  No. mature males=  4
No. immature females=  0  No. mature females=  3
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  .75  females/male
Overall sex ratio=  .75  females/male

summary data on file  13
```

```
                  5 inch Angling Lake Mesh Size Effects Whitefish

                                                                         Frequency mature fish
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight     S.E.(W)    --------------------
                                                                            Male     Female
------------------------------------------------------------------------------------------------
 0      0      0.00       0.00        0.00         0.00         0.00        0.00       0.00
 1      0      0.00       0.00        0.00         0.00         0.00        0.00       0.00
 2      0      0.00       0.00        0.00         0.00         0.00        0.00       0.00
 3      0      0.00       0.00        0.00         0.00         0.00        0.00       0.00
 4      0      0.00       0.00        0.00         0.00         0.00        0.00       0.00
 5      0      0.00       0.00        0.00         0.00         0.00        0.00       0.00
 6      2     28.57     418.50       22.50      1175.00       125.00        0.00       0.00
 7      2     28.57     402.00        7.00      1000.00        40.00        0.00     100.00
 8      0      0.00       0.00        0.00         0.00         0.00      100.00     100.00
 9      1     14.29     394.00        0.00       980.00         0.00        0.00       0.00
10      1     14.29     385.00        0.00       800.00         0.00        0.00     100.00
11      0      0.00       0.00        0.00         0.00         0.00        0.00     100.00
12      0      0.00       0.00        0.00         0.00         0.00        0.00       0.00
13      1     14.29     438.00        0.00      1220.00         0.00        0.00       0.00
                                                                          100.00       0.00
------------------------------------------------------------------------------------------------
Total no. fish=  7
Total weight of all fish=  4350
Overall mean length=  407.5  S.E.=  416.5994
Overall mean weight=  1035  S.E.=  1060.837
No. immature males=  0  No. mature males=  2
No. immature females=  0  No. mature females=  5
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  2.5  females/male
Overall sex ratio=  2.5  females/male

summary data on file  14
```

```
                    1.5 inch Angling Lake Mesh Size Effects Pike

                                                                  Frequency mature fish
Age   No.   Freq.(%)  Mean length   S.E.(L)  Mean weight    S.E.(W)   --------------------
-------------------------------------------------------------------     Male     Female
----------------------------------------------------------------------------------------
 0     0      0.00        0.00        0.00        0.00        0.00      0.00      0.00
 1     1     10.00      294.00        0.00      160.00        0.00      0.00      0.00
 2     4     40.00      327.75       26.41      255.00       83.12      0.00      0.00
 3     1     10.00      354.00        0.00      300.00        0.00      0.00      0.00
 4     1     10.00      406.00        0.00      410.00        0.00      0.00    100.00
 5     0      0.00        0.00        0.00        0.00        0.00      0.00      0.00
 6     0      0.00        0.00        0.00        0.00        0.00      0.00      0.00
 7     0      0.00        0.00        0.00        0.00        0.00      0.00      0.00
 8     2     20.00      733.00       65.00     2935.00     1065.00    100.00    100.00
 9     1     10.00      782.00        0.00     3980.00        0.00    100.00      0.00
----------------------------------------------------------------------------------------
Total no. fish=  10
Total weight of all fish=  6890
Overall mean length=  482.7917  S.E.=  88.37314
Overall mean weight=  1340  S.E.=  683.8555
No. immature males=  1  No. mature males=  2
No. immature females=  5  No. mature females=  2
Immature sex ratio=  5  females/male
Mature sex ratio=  1  females/male
Overall sex ratio=  2.333333  females/male

summary data on file  3
```

```
                       2 inch Angling Lake Mesh Size Effects Pike

                                                                    Frequency mature fish
                                                                   ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight     S.E.(W)       Male    Female
-------------------------------------------------------------------------------------------

 0      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 1      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 2      5     18.52      349.80       10.37      286.00         24.82        0.00      0.00
 3      8     29.63      405.25       17.51      500.00         69.26       33.33     40.00
 4      3     11.11      438.00       24.85      603.33        124.14      100.00    100.00
 5      1      3.70      514.00        0.00     1020.00          0.00      100.00      0.00
 6      1      3.70      580.00        0.00     1100.00          0.00        0.00      0.00
 7      2      7.41      590.00       34.00     1455.00        405.00        0.00    100.00
 8      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
 9      0      0.00        0.00        0.00        0.00          0.00        0.00      0.00
10      4     14.81      817.75       56.96     4782.50        847.64      100.00    100.00
11      3     11.11      869.33       27.38     5026.67        291.79        0.00    100.00
-------------------------------------------------------------------------------------------

Total no. fish=  27
Total weight of all fish=  44360
Overall mean length=  570.5168  S.E.=  183.249
Overall mean weight=  1846.688  S.E.=  951.7299
No. immature males=  2  No. mature males=  4
No. immature females=  9  No. mature females=  12
Immature sex ratio=  4.5  females/male
Mature sex ratio=  3  females/male
Overall sex ratio=  3.5  females/male

summary data on file  4
```

```
                    3 inch Angling Lake Mesh Size Effects Pike

                                                                      Frequency mature fish
                                                                      ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight    S.E.(W)      Male     Female
-------------------------------------------------------------------------------------------

 0      0      0.00        0.00        0.00         0.00        0.00        0.00      0.00
 1      0      0.00        0.00        0.00         0.00        0.00        0.00      0.00
 2      0      0.00        0.00        0.00         0.00        0.00        0.00      0.00
 3      1      2.70      521.00        0.00      1080.00        0.00      100.00      0.00
 4      6     16.22      513.67       22.14       993.33      143.19       33.33    100.00
 5      6     16.22      557.17       23.90      1270.00      194.65      100.00     50.00
 6      8     21.62      657.50       31.47      2110.00      307.37        0.00    100.00
 7      5     13.51      661.40       26.93      2160.00      399.11      100.00    100.00
 8      6     16.22      702.67       37.14      2698.33      396.25      100.00    100.00
 9      0      0.00        0.00        0.00         0.00        0.00        0.00      0.00
10      2      5.41      820.50       22.50      4880.00      420.00        0.00    100.00
11      3      8.11      861.33       16.46      5226.67      210.90      100.00    100.00
-------------------------------------------------------------------------------------------
Total no. fish=  37
Total weight of all fish=  82890
Overall mean length=  661.9043  S.E.=  286.7243
Overall mean weight=  2552.292  S.E.=  1317.397
No. immature males=  2  No. mature males=  7
No. immature females=  2  No. mature females=  26
Immature sex ratio=  1  females/male
Mature sex ratio=  3.714286  females/male
Overall sex ratio=  3.111111  females/male

summary data on file  5
```

```
                      3.75 inch Angling Lake Mesh Size Effects Pike

                                                                    Frequency mature fish
                                                                    ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight    S.E.(W)      Male    Female
------------------------------------------------------------------------------------------

 0      0      0.00        0.00        0.00         0.00        0.00       0.00      0.00
 1      0      0.00        0.00        0.00         0.00        0.00       0.00      0.00
 2      0      0.00        0.00        0.00         0.00        0.00       0.00      0.00
 3      1      2.63      513.00        0.00      1000.00        0.00       0.00    100.00
 4      1      2.63      520.00        0.00      1240.00        0.00     100.00      0.00
 5      5     13.16      612.20       32.95      1712.00      336.68     100.00    100.00
 6      4     10.53      616.00       38.36      1690.00      331.69      75.00      0.00
 7      6     15.79      648.33       19.01      1983.33      214.78     100.00    100.00
 8      7     18.42      705.43       23.25      2808.57      350.96       0.00    100.00
 9      5     13.16      735.60       54.87      3164.00      614.07     100.00    100.00
10      3      7.89      750.00       52.17      3453.33      816.14     100.00    100.00
11      2      5.26      891.00       19.00      5400.00      600.00     100.00    100.00
12      1      2.63      968.00        0.00      6515.00        0.00       0.00    100.00
13      2      5.26      867.00       22.00      4855.00      525.00     100.00      0.00
14      0      0.00        0.00        0.00         0.00        0.00       0.00      0.00
15      1      2.63      956.00        0.00      6110.00        0.00       0.00    100.00
------------------------------------------------------------------------------------------

Total no. fish=  38
Total weight of all fish=  93570
Overall mean length=  731.8802  S.E.=  252.0654
Overall mean weight=  3327.603  S.E.=  1202.961
No. immature males=  1  No. mature males=  15
No. immature females=  0  No. mature females=  22
Immature sex ratio=  0  females/male
Mature sex ratio=  1.466667  females/male
Overall sex ratio=  1.375  females/male

summary data on file  6
```

```
                    4.25 inch Angling Lake Mesh Size Effects Pike

                                                                             Frequency mature fish
                                                                             ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight    S.E.(W)       Male     Female
------------------------------------------------------------------------------------------------

 0      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
 1      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
 2      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
 3      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
 4      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
 5      1      7.14     461.00         0.00      2080.00         0.00         0.00     100.00
 6      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
 7      5     35.71     745.60        26.59      3092.00       293.96       100.00     100.00
 8      1      7.14     668.00         0.00      2350.00         0.00         0.00     100.00
 9      2     14.29     858.00        38.00      5310.00      1290.00         0.00     100.00
10      3     21.43     807.00        33.47      4523.33       990.24         0.00     100.00
11      1      7.14     886.00         0.00      5360.00         0.00         0.00     100.00
12      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
13      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
14      0      0.00       0.00         0.00         0.00         0.00         0.00       0.00
15      1      7.14     944.00         0.00      6230.00         0.00         0.00     100.00
------------------------------------------------------------------------------------------------

Total no. fish=  14
Total weight of all fish=  39650
Overall mean length=  767.0857  S.E.=  597.0948
Overall mean weight=  4135.048  S.E.=  2844.429
No. immature males=  0  No. mature males=  1
No. immature females=  0  No. mature females=  13
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  13  females/male
Overall sex ratio=  13  females/male

summary data on file  7
```

```
                    5 inch Angling Lake Mesh Size Effects Pike

                                                                          Frequency mature fish
Age   No.   Freq.(%)  Mean length   S.E.(L)   Mean weight     S.E.(W)     ---------------------
                                                                            Male     Female
-------------------------------------------------------------------------------------------------
 0     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
 1     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
 2     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
 3     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
 4     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
 5     1     14.29      626.00        0.00       1800.00         0.00       0.00     100.00
 6     1     14.29      730.00        0.00       3220.00         0.00       0.00     100.00
 7     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
 8     2     28.57      791.50       14.50       4055.00       105.00       0.00     100.00
 9     1     14.29      896.00        0.00       6220.00         0.00       0.00     100.00
10     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
11     0      0.00        0.00        0.00          0.00         0.00       0.00       0.00
12     2     28.57      912.00       10.00       5530.00       570.00       0.00     100.00
-------------------------------------------------------------------------------------------------
Total no. fish=  7
Total weight of all fish=  19170
Overall mean length=  791.1  S.E.=  978.5061
Overall mean weight=  4165  S.E.=  4858.434
No. immature males=  0  No. mature males=  0
No. immature females=  0  No. mature females=  7
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  1.701412E+38  females/male
Overall sex ratio=  1.701412E+38  females/male

summary data on file  8
```

```
                     1.5 inch Angling Lake Mesh Size Effects Walleye

                                                                       Frequency mature fish
                                                                      ----------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight    S.E.(W)      Male    Female
----------------------------------------------------------------------------------------------

 0      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 1      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 2      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 3      4     26.67      185.50        3.23        62.50         6.29     100.00     33.33
 4      5     33.33      215.20        5.46        98.00        12.81     100.00     75.00
 5      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 6      1      6.67      282.00        0.00       210.00         0.00       0.00    100.00
 7      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 8      2     13.33      384.00       26.00       585.00       135.00     100.00      0.00
 9      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
10      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
11      1      6.67      374.00        0.00       570.00         0.00       0.00    100.00
12      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
13      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
14      1      6.67      230.00        0.00       100.00         0.00       0.00      0.00
15      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
16      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
17      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
18      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
19      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
20      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
21      1      6.67      538.00        0.00      1700.00         0.00       0.00    100.00
----------------------------------------------------------------------------------------------

Total no. fish=  15
Total weight of all fish=  1910
Overall mean length=  315.5286  S.E.=  47.05957
Overall mean weight=  475.0714  S.E.=  220.653
No. immature males=  0  No. mature males=  3
No. immature females=  5  No. mature females=  7
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  2.333333  females/male
Overall sex ratio=  4  females/male

summary data on file  15
```

```
                        2 inch Angling Lake Mesh Size Effects Walleye

                                                                           Frequency mature fish
                                                                           ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight      S.E.(W)         Male    Female
----------------------------------------------------------------------------------------------
 0      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
 1      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
 2      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
 3      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
 4      6     46.15      236.83        5.00       128.33          9.46        100.00      0.00
 5      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
 6      2     15.38      306.00       26.00       290.00         70.00          0.00      0.00
 7      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
 8      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
 9      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
10      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
11      2     15.38      348.00       16.00       420.00         40.00        100.00      0.00
12      1      7.69      413.00        0.00       800.00          0.00          0.00    100.00
13      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
14      1      7.69      416.00        0.00       800.00          0.00          0.00    100.00
15      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
16      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
17      0      0.00        0.00        0.00         0.00          0.00          0.00      0.00
18      1      7.69      504.00        0.00      1410.00          0.00          0.00    100.00
----------------------------------------------------------------------------------------------

Total no. fish=  13
Total weight of all fish=  2190
Overall mean length=  370.6389  S.E.=  166.7486
Overall mean weight=  641.389  S.E.=  395.8757
No. immature males=  0  No. mature males=  2
No. immature females=  8  No. mature females=  3
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  1.5  females/male
Overall sex ratio=  5.5  females/male

summary data on file  16
```

```
                     3 inch Angling Lake Mesh Size Effects Walleye

                                                                   Frequency mature fish
Age   No.   Freq.(%)  Mean length   S.E.(L)   Mean weight    S.E.(W)   --------------------
                                                                        Male      Female
---------------------------------------------------------------------------------------------

 0     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 1     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 2     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 3     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 4     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 5     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 6     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 7     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 8     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
 9     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
10     2      8.70     384.00       24.00      605.00       145.00      0.00      50.00
11     5     21.74     364.60       13.82      508.00        69.46      0.00      40.00
12     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
13     2      8.70     416.00        4.00      750.00         0.00      0.00       0.00
14     6     26.09     432.00       19.77      860.00       119.64      0.00      40.00
15     2      8.70     399.00        6.00      650.00        50.00      0.00     100.00
16     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
17     1      4.35     414.00        0.00      750.00         0.00      0.00     100.00
18     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
19     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
20     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
21     3     13.04     518.67       29.17     1403.33       278.71      0.00     100.00
22     1      4.35     551.00        0.00     1680.00         0.00      0.00     100.00
23     0      0.00       0.00        0.00        0.00         0.00      0.00       0.00
24     1      4.35     508.00        0.00     1400.00         0.00      0.00     100.00
---------------------------------------------------------------------------------------------
Total no. fish=  23
Total weight of all fish=  15920
Overall mean length=  443.0297  S.E.=  153.3542
Overall mean weight=  956.2592  S.E.=  345.6646
No. immature males=  3  No. mature males=  0
No. immature females=  8  No. mature females=  12
Immature se  ratio=  2.666667  females/male
Mature sex   tio=  1.701412E+38  females/male
Overall sex ratio=  6.666667  females/male

summary data on file  17
```

```
                     3.75 inch Angling Lake Mesh Size Effects Walleye

                                                                      Frequency mature fish
Age    No.   Freq.(%)  Mean length    S.E.(L)   Mean weight     S.E.(W)    --------------------
                                                                              Male     Female
-------------------------------------------------------------------------------------------------

  0     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  1     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  2     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  3     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  4     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  5     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  6     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  7     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
  8     1      3.85      378.00         0.00       550.00         0.00        0.00      0.00
  9     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
 10     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
 11     3     11.54      382.33        16.17       576.67        49.78        0.00     66.67
 12     2      7.69      407.50        12.50       695.00        75.00        0.00     50.00
 13     1      3.85      431.00         0.00       770.00         0.00        0.00    100.00
 14     8     30.77      421.75        11.26       758.75        46.62      100.00     71.43
 15     1      3.85      420.00         0.00       750.00         0.00        0.00    100.00
 16     2      7.69      451.00         7.00       895.00        45.00        0.00    100.00
 17     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
 18     1      3.85      400.00         0.00       610.00         0.00        0.00      0.00
 19     1      3.85      513.00         0.00      1240.00         0.00        0.00    100.00
 20     1      3.85      479.00         0.00      1220.00         0.00        0.00    100.00
 21     4     15.38      523.00         9.41      1380.00        91.56        0.00    100.00
 22     0      0.00        0.00         0.00         0.00         0.00        0.00    100.00
 23     0      0.00        0.00         0.00         0.00         0.00        0.00      0.00
 24     1      3.85      528.00         0.00      1550.00         0.00        0.00    100.00
-------------------------------------------------------------------------------------------------

Total no. fish=  26
Total weight of all fish=  16500
Overall mean length=  444.5486  S.E.=  162.6423
Overall mean weight=  916.2848  S.E.=  370.4318
No. immature males=  1  No. mature males=  1
No. immature females=  5  No. mature females=  19
Immature sex ratio=  5  females/male
Mature sex ratio=  19  females/male
Overall sex ratio=  12  females/male

summary data on file  18
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                 4.25 inch Angling Lake Mesh Size Effects Walleye

                                                                    Frequency mature fish
                                                                    ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight     S.E.(W)      Male    Female
-------------------------------------------------------------------------------------------

 0      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 1      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 2      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 3      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 4      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 5      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 6      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 7      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 8      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
 9      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
10      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
11      1     10.00      411.00        0.00       760.00         0.00       0.00    100.00
12      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
13      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
14      2     20.00      492.00        2.00      1160.00        10.00       0.00    100.00
15      1     10.00      464.00        0.00      1020.00         0.00       0.00    100.00
16      1     10.00      462.00        0.00       980.00         0.00       0.00    100.00
17      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
18      1     10.00      472.00        0.00      1000.00         0.00     100.00      0.00
19      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
20      2     20.00      514.00       20.00      1305.00        95.00     100.00      0.00
21      1     10.00      557.00        0.00      1780.00         0.00       0.00    100.00
22      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
23      0      0.00        0.00        0.00         0.00         0.00       0.00      0.00
24      1     10.00      467.00        0.00      1060.00         0.00       0.00    100.00
-------------------------------------------------------------------------------------------

Total no. fish=  10
Total weight of all fish=  4930
Overall mean length=  479.875  S.E.=  323.9273
Overall mean weight=  1133.125  S.E.=  717.5751
No. immature males=  0  No. mature males=  3
No. immature females=  0  No. mature females=  7
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  2.333333  females/male
Overall sex ratio=  2.333333  females/male

summary data on file  19
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                    5 inch Angling Lake Mesh Size Effects Walleye

                                                                     Frequency mature fish
                                                                     ---------------------
Age    No.   Freq.(%)  Mean length   S.E.(L)   Mean weight    S.E.(W)     Male    Female
-----------------------------------------------------------------------------------------

 0      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 1      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 2      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 3      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 4      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 5      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 6      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 7      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 8      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
 9      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
10      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
11      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
12      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
13      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
14      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
15      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
16      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
17      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
18      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
19      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
20      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
21      3     75.00     540.67        37.39     1686.67       281.98       0.00    66.67
22      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
23      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
24      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
25      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
26      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
27      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
28      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
29      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
30      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
31      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
32      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
33      0      0.00       0.00         0.00        0.00         0.00       0.00     0.00
34      1     25.00     587.00         0.00     2000.00         0.00       0.00   100.00
-----------------------------------------------------------------------------------------

Total no. fish=  4
Total weight of all fish=  5060
Overall mean length=  563.8334  S.E.=  1964.603
Overall mean weight=  1843.333  S.E.=  4424.706
No. immature males=  0  No. mature males=  0
No. immature females=  1  No. mature females=  3
Immature sex ratio=  1.701412E+38  females/male
Mature sex ratio=  1.701412E+38  females/male
Overall sex ratio=  1.701412E+38  females/male

summary data on file  20
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APPENDIX 15

Floy tag recapture summary for Nelson River brook trout sampled during the 1985-87 sampling seasons

Brook Trout Recapture Summary.

TAG #	DATE	LOCATION
48.371	09/23/85	SKY PILOT CK. @ MOUTH
	12/05/85	GILLAM TOWNSITE.LOCAL ANGLER.NO INFORMATION
48.399	09/20/85	LIMESTONE R. @ 5-MILE HOLE
	10/09/85	"FOUND @ 5-MILE HOLE"RETURNED TO GILLAM C.O.'S
48.454	09/12/85	LIMESTONE R. 5-MILE HOLE
	10/08/85	LIMESTONE R.5-MILE HOLE.CAPT.&RELEASED.LCL. ANGLER
I001006	08/03/87	CN CK.,1/2KM ABOVE CULVERTS
	09/08/87	CN CK. FOUND DEAD 100M BELOW FENCE #1
I001012	08/03/87	CN CK.,1/2KM ABOVE CULVERTS
	09/11/87	CN CK.
I001043	08/28/86	LIMESTONE R. 5-MILE HOLE
	10/01/87	LIMESTONE R. 5-MILE HOLE.NO OTHER INFORMATION
I001052	[illegible]/01/87	12-MILE CK.
	[illegible]/17/87	12-MILE CK.,100M ABOVE FENCE
I001075	[illegible]/03/87	MOONDANCE CK.
	[illegible]/29/89	MOONDANCE CK. @ MOUTH
I001080	09/09/86	LIMESTONE R. @ 5-MILE HOLE
	08/16/87	BIRD CK. @ MOUTH.R.BEARDY.LOCAL ANGLER RTURN
I001220	10/15/87	12-MILE CK..100M ABOVE FENCE
	10/17/87	12-MILE CK.,100M ABOVE FENCE
I001426	08/09/87	LIMESTONE R..NEAR MOUTH OF CN CK.
	09/26/87	9-MILE CK.
I001433	09/06/87	MOONDANCE CK.
	09/23/87	MOONDANCE CK.
I001439	09/10/87	MOONDANCE CK.
	09/27/87	LIMESTONE R.@5-MILE HOLE.**RADIO TAGGED 49.117****
I001441	09/11/87	MOONDANCE CK.
	09/22/87	MOONDANCE CK.
I001478	10/02/87	WILSON CK.
	10/03/87	WILSON CK.
	10/14/87	WILSON CK.
I001512	08/17/87	9-MILE CK.,15M ABOVE FENCE
	08/29/87	9-MILE CK.

Brook Trout Recapture Summary.

TAG #	DATE	LOCATION
I001515	08/28/87	9-MILE CK. @ MOUTH
	09/13/87	9-MILE CK.
	09/20/87	9-MILE CK.
I001517	08/28/87	9-MILE CK.,10M ABOVE FENCE
	08/29/87	9-MILE CK.
I001519	09/09/87	9-MILE CK.,15M ABOVE FENCE
	10/11/87	9-MILE CK.,15M ABOVE FENCE,RELEASED DOWNSTREAM
I001520	09/10/87	12-MILE CK.,10M ABOVE FENCE
	09/23/87	12-MILE CK.
I001524	09/12/87	9-MILE CK.
	10/08/87	9-MILE CK.
I001660	09/07/86	9-MILE CK. SPAWNING POOL
	10/02/87	9-MILE CK.
I001661	09/07/86	LIMESTONE R. @ 5-MILE HOLE
	09/09/86	LIMESTONE R. @ 5-MILE HOLE
I001667	06/01/87	MOONDANCE CK.
	06/23/87	MOONDANCE CK. ABOVE FENCE
I001668	06/06/87	CN CK.
	06/09/87	CN CK.
	06/19/87	CN CK.,50M ABOVE MOUTH
I001669	06/04/87	CN CK.,100M UP FROM MOUTH
	06/19/87	CN CK.,125M UP FROM MOUTH
I001671	06/05/87	MOONDANCE CK.
	07/04/87	MOONDANCE CK.
	07/23/87	MOONDANCE CK. 300M ABOVE FENCE
I001826	09/10/87	9-MILE CK. @ MOUTH
	09/13/87	9-MILE CK.
	10/03/87	9-MILE CK.
I001832	09/13/87	9-MILE CK.
	09/13/87	9-MILE CK.
	10/02/87	9-MILE CK.
I001837	09/16/87	9-MILE CK.
	10/03/87	9-MILE CK.
I001843	09/26/87	9-MILE CK.
	10/02/87	9-MILE CK.
	10/16/87	9-MILE CK.

Brook Trout Recapture Summary.

TAG #	DATE	LOCATION
I001850	09/18/87	9-MILE CK.
	10/02/87	9-MILE CK.
DR00456	07/14/85	MOONDANCE CK.
	09/14/87	MOONDANCE CK.
DR00458	07/14/85	MOONDANCE CK.
	08/09/85	MOONDANCE CK. 1KM UP
DR00459	07/14/85	MOONDANCE CK.
	05/26/87	MOONDANCE CK.
	05/23/87	MOONDANCE CK.
	07/03/87	MOONDANCE CK. 200M ABOVE FENCE
	07/06/87	MOONDANCE CK.
DR00461	07/14/85	MOONDANCE CK.@MOUTH
	08/10/85	MOONDANCE CK. JUST UP MOUTH
DR00470	07/17/85	MOONDANCE CK.@MOUTH
	08/10/85	MOONDANCE CK. @MOUTH
DR00492	08/16/85	9-MILE CK. 1KM UP
	09/04/85	9-MILE CK. 1KM UP
	09/17/85	9-MILE CK. @MOUTH
DR00493	08/16/85	9-MILE CK. 1KM UP
	09/03/85	9-MILE CK. 1KM UP
DR00496	08/16/85	9-MILE CK. 1KM UP
	09/04/85	9-MILE CK. 1KM UP
DR00497	08/16/85	9-MILE CK. 1KM UP
	09/04/85	9-MILE CK. 1KM UP
DR00499	08/16/85	9-MILE CK. 1KM UP
	09/03/85	9-MILE CK. 1KM UP
	09/04/85	9-MILE CK. 1KM UP
DR00500	08/16/85	9-MILE CK. 1KM UP
	09/03/85	9-MILE CK. 1KM UP
DR00507	09/02/85	9-MILE CK. @ MOUTH
	09/03/85	9-MILE CK. @ MOUTH
	09/17/85	9-MILE CK. @ MOUTH
DR00508	09/03/85	9-MILE CK. @ MOUTH
	09/04/85	9-MILE CK. @ MOUTH
	10/01/86	LIMESTONE R. 5-MILE HOLE
	08/16/87	9-MILE CK. R.BEARDY,LOCAL ANGLER RETURN

Brook Trout Recapture Summary.

TAG #	DATE	LOCATION
DR00510	09/03/85	9-MILE CK. @ MOUTH
	09/16/85	9-MILE CK. @ MOUTH
	09/17/85	9-MILE CK. @ MOUTH
DR00511	09/03/85	9-MILE CK. 1KM UPSTREAM
	09/04/85	9-MILE CK. 1KM UPSTREAM
DR00512	09/03/85	9-MILE CK. 1KM UPSTREAM
	09/04/85	9-MILE CK. 1KM UPSTREAM
DR00514	09/03/85	9-MILE CK. 1KM UPSTREAM
	09/07/86	9-MILE CK.@ SPAWNING POOL
	09/27/87	9-MILE CK.
DR00515	09/03/85	9-MILE CK.1KM UPSTREAM
	09/04/85	9-MILE CK.1KM UPSTREAM
DR00516	09/03/85	9-MILE CK.1KM UPSTREAM
	7/29/87	9-MILE CK.
DR00518	09/03/85	9-MILE CK.@ MOUTH
	9/04/85	9-MILE CK.@ MOUTH
	09/17/85	9-MILE CK.@ MOUTH ,RETAGGED #DR00527 ************
DR00522/23	09/04/85	9-MILE CK.1KM UPSTREAM
	09/27/86	9-MILE CK.@ SPAWNING POOL
DR00536	09/07/85	LIMESTONE R. 7 MILES UPSTREAM
	09/17/85	9-MILE CK. @ MOUTH
	09/17/87	9-MILE CK. R.BEARDY,LOCAL ANGLER RETURN
DR00545	09/09/85	BIRD CK. , BELOW CULVERTS
	08/01/87	LIMESTONE R.,@CN CK.****RETAGGED #I001502 *****
DR00553	09/09/85	LIMESTONE R. JUST BELOW CULVERTS
	10/14/85	LIMESTONE R. @ 5-MILE HOLE,LOCAL ANGLER RETURN
DR00555	09/09/85	LIMESTONE R. IN CULVERTS
	10/14/85	LIMESTONE R. @ 5-MILE HOLE,LOCAL ANGLER RETURN
DR00556	09/09/85	LIMESTONE R. IN CULVERTS
	10/14/85	LIMESTONE R. @ 5-MILE HOLE,LOCAL ANGLER RETURN
DR00558	09/10/85	LIMESTONE R. 1 MILE UP FROM BIRD CK. MOUTH
	10/12/85	LIMESTONE R. 5-MILE HOLE,LOCAL ANGLER RETURN
DR00559	09/10/85	LIMESTONE R. BELOW CULVERTS
	10/14/85	LIMESTONE R. 5-MILE HOLE,LOCAL ANGLER RETURN

Brook Trout Recapture Summary.

TAG #	DATE	LOCATION
DR00576	06/19/87	MOONDANCE CK.
	07/03/87	MOONDANCE CK. 200M ABOVE FENCE
DR00577	06/19/87	MOONDANCE CK.
	07/01/87	MOONDANCE CK. 200M ABOVE FENCE
DR00586	06/23/87	MOONDANCE CK. 50M ABOVE FENCE
	07/03/87	MOONDANCE CK.200M ABOVE FENCE
DR00587	06/23/87	MOONDANCE CK. 50M ABOVE FENCE
	07/23/87	MOONDANCE CK.200M ABOVE FENCE
DR00588	06/23/87	MOONDANCE CK.100M ABOVE FENCE
	06/25/87	MOONDANCE CK.
	07/03/87	MOONDANCE CK. 200M ABOVE FENCE
	08/30/87	MOONDANCE CK.
DR00594	06/24/87	MOONDANCE CK.
	07/01/87	MOONDANCE CK.200M ABOVE FENCE
DR00599	07/04/87	MOONDANCE CK.
	07/22/87	MOONDANCE CK.
DR00600	07/06/87	MOONDANCE CK.
	09/05/87	MOONDANCE CK.
DR00801	09/14/85	SKY PILOT CK. @ AA POOL
	09/19/85	SKY PILOT CK. @ AA POOL
DR00803	10/01/86	LIMESTONE R. 5-MILE
	09/13/87	9-MILE CK.
DR00808	05/27/87	CN CK.
	06/19/87	CN CK.,125M UP FROM MOUTH
DR00822	06/22/87	MOONDANCE CK.
	07/03/87	MOONDANCE CK. 200M ABOVE FENCE
	08/29/87	MOONDANCE CK.
	09/07/87	MOONDANCE CK.
DR00823	06/21/87	MOONDANCE CK.
	07/03/87	MOONDANCE CK. 300M ABOVE FENCE
DR00827	08/20/85	SKY PILOT CK. 800M DOWN FROM AA POOL
	09/14/85	SKY PILOT CK. @ AA POOL
DR00836	08/22/85	SKY PILOT CK.
	09/17/85	SKY PILOT CK. @ AA POOL
	09/22/85	SKY PILOT CK. @ AAPOOL

Brook Trout Recapture Summary.

TAG #	DATE	LOCATION
DR00838	08/22/85	SKY PILOT CK. 800M DOWN FROM AA POOL
	09/17/85	SKY PILOT CK. @ AA POOL
	09/19/85	SKY PILOT CK. @ AA POOL
DR00851	09/14/85	SKY PILOY CK. @ AA POOL
	09/17/85	SKY PILOT CK. @ AA POOL
DR00852	09/14/85	SKY PILOT CK. @ AA POOL
	09/17/85	SKY PILOT CK. @ AA POOL
DR00853	09/14/85	SKY PILOT CK. @ AA POOL
	09/17/85	SKY PILOT CK. @ AA POOL
DR00885	08/19/85	SKY PILOT CK.800M DOWN FROM AA POOL
	09/16/85	SKY PILOT CK. @ AA POOL
DR00892	08/15/85	SKY PILOT AA POOL
	09/24/85	SKY PILOT @MOUTH,TAGGED RADIO TRANS. 48.961 MHZ
UMX00572	05/31/87	MOONDANCE CK.
	09/22/87	MOONDANCE CK.
UMX00756	09/16/85	SKY PILOT CK. AA POOL
	09/17/85	SKY PILOT CK. AA POOL
UMX00758	09/16/85	SKY PILOT CK. AA POOL
	09/17/85	SKY PILOT CK. AA POOL
UMX00760	09/17/85	SKY PILOT CK. AA POOL
	09/22/85	SKY PILOT CK. AA POOL
UMX00771	09/17/85	SKY PILOT CK. AA POOL
	09/18/85	SKY PILOT CK. AA POOL
UMX00773	09/17/85	SKY PILOT CK. AA POOL
	09/19/85	SKY PILOT CK. AA POOL
UMX00775	09/17/85	SKY PILOT CK. AA POOL
	09/19/85	SKY PILOT CK. AA POOL
UMX00784	09/19/85	SKY PILOT CK. AA POOL
	09/19/85	SKY PILOT CK. AA POOL
UMX00812	07/07/87	MOONDANCE CK.100M ABOVE FENCE
	09/08/87	MOONDANCE CK.